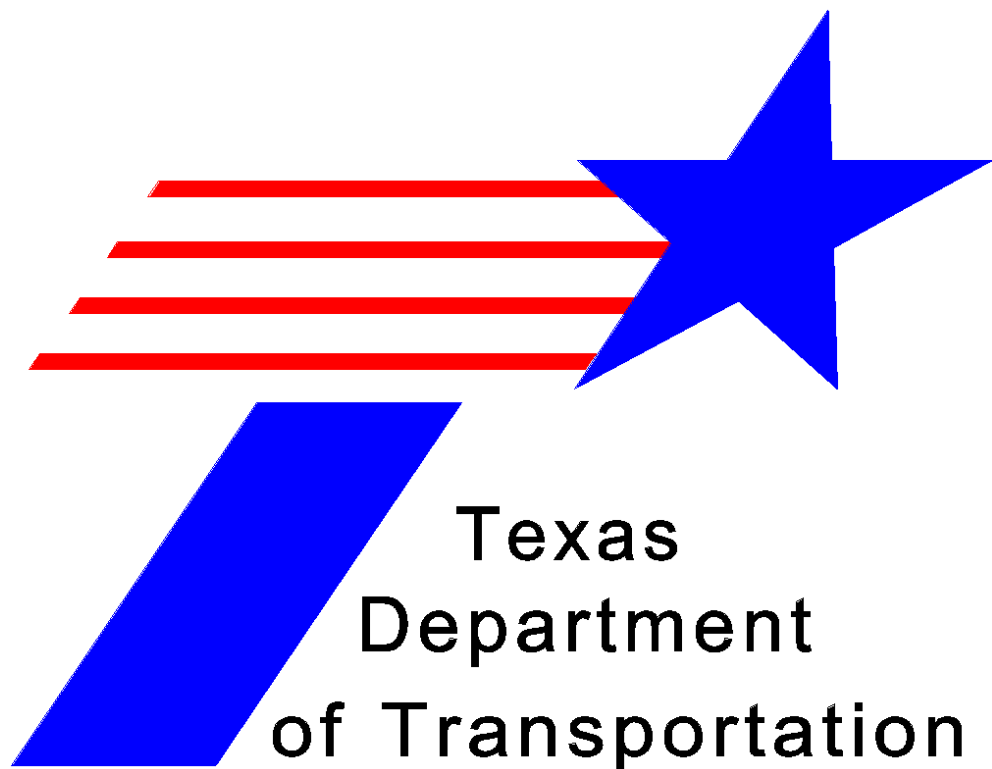


Highway Illumination Manual



November 2003

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Highway Illumination Manual
November 2003
Manual Notices

Manual Notice 2003-1

To: Holders of Subject Manual

From: Carlos A. Lopez, P.E. Traffic Operations Division

Manual: *Highway Illumination Manual*

Effective Date: November 3, 2003

Purpose

To establish and revise internal procedures and requirements necessary to implement TxDOT's administrative rules on continuous and safety lighting systems as set forth in 43 TAC 25.11, and to provide information relevant to highway illumination.

Supersedes

This manual supersedes the *Highway Illumination Volume* of the *Traffic Operations Manual* issued under Manual Notice 95-1.

Significant Changes

This manual represents a nearly complete revision of the superseded manual. Significant changes are as follows:

- ◆ the expansion of the list of references to related literature (Chapter 1)
- ◆ the addition of an entire chapter on the master lighting plan concept (Chapter 3)
- ◆ the addition of a section on "Illumination Levels" (Chapter 6)
- ◆ the addition of a section on "Glare and Sky Glow Issues" (Chapter 6)
- ◆ the extensive revision of light pole spacing and mounting height guidelines (Chapter 6)
- ◆ the removal of most metric measurement equivalents throughout the manual
- ◆ the removal or revision of obsolete technical information throughout the manual.

Review History

General Counsel Review. The Office of General Counsel reviewed the draft version of this manual and found it legally sufficient for its intended purpose.

Audit Office Review. The Audit Office reviewed the draft version of this manual and offered many comments and suggestions, which we considered and incorporated as appropriate.

District and Division Review. Potential users in several districts and concerned divisions reviewed the draft versions of this manual. We received numerous comments and suggestions, which we considered and incorporated as appropriate.

Content

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Index (print version only)
13 labeled tab dividers (print version only)

Contact

Address questions concerning information contained in this manual to Karl Burkett of the Traffic Operations Division, 512-416-3121.

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Chapter 1

Introduction

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Section 1

Overview

Purpose of Manual

The purpose of this manual is to provide procedures, guidelines, and information concerning highway illumination.

Users of Manual

This manual is intended for use by:

- ◆ planners and designers of highway illumination systems
- ◆ construction and maintenance personnel involved with highway illumination.

Although this manual contains information on electrical circuits, it does not cover the full range of knowledge necessary to design, install, or maintain electrical circuitry.

Training

The Texas Department of Transportation (TxDOT) offers the Illumination Design training course (DES 103), which is recommended for designers of highway illumination systems.

Texas State Technical College in Waco offers the Basic Maintenance Electrician Course (MNT 100), which is recommended for inspectors and maintenance personnel.

Texas Engineering Extension Service (TEEX) offers two TxDOT courses recommended for engineers and technicians involved in design, construction, or maintenance of illumination and electrical systems:

- ◆ Electrical Systems Course (TRF 450)
- ◆ Grounding Practices and Applications (TRF 451).

Experience

Personnel with practical electrical experience can provide valuable expertise in the inspection of illumination projects and the maintenance of lighting. Those holding or having recently held an electrical license can help assure conformity with the National Electrical Code and good electrical practices.

References

The following table lists publications that may serve as additional references for issues related to highway illumination.

References Related to Highway Illumination	
Publication	Source
<ul style="list-style-type: none"> ♦ <i>Standard Specifications for Construction of Highways, Streets, and Bridges</i> ♦ <i>Traffic Operations Standard Plans</i> (also variously referred to as <i>Traffic Control Standard Sheets</i> or <i>Traffic Engineering Standard Plan Sheets</i>). This publication includes: <ul style="list-style-type: none"> • Electrical Details (ED) • High Mast Illumination Details (HMID) • Roadway Illumination Details (RID). ♦ <i>Texas Manual on Uniform Traffic Control Devices (TMUTCD)</i> ♦ other TxDOT manuals 	<p>Texas Department of Transportation (TxDOT) Attn.: General Services Division 125 E. 11th Street Austin TX 78701-2483 Phone: 512-465-7326 Internet: www.dot.state.tx.us</p> <p><i>Note:</i> Many TxDOT Manuals (including this one) are published on-line and are freely available at the following websites:</p> <ul style="list-style-type: none"> ♦ Internet: http://manuals.dot.state.tx.us/dynaweb ♦ TxDOT Crossroads (internal only): http://txdot-manuals/dynaweb
<i>National Electrical Code Handbook</i>	<p>National Fire Protection Association (NFPA) Batterymarch Park Quincy MA 02269-9990 Phone: 800-344-3555 Internet: www.nfpa.org</p>
<ul style="list-style-type: none"> ♦ <i>Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals</i> ♦ <i>An Informational Guide on Roadway Lighting</i> 	<p>American Association of State Highway and Transportation Officials (AASHTO) 444 N. Capitol street NW, Suite 225 Washington DC 20001 Phone: 202-624-5800 Internet: www.transportation.org/aashto/home.nsf/FrontPage</p>
<ul style="list-style-type: none"> ♦ <i>IESNA Lighting Handbook: Reference and Application</i> (HB-9-00) ♦ <i>Roadway Lighting</i> (RP-8-00) ♦ <i>IESNA Recommended Practices for Tunnel Lighting</i> (RP-22-96) ♦ <i>Nomenclature and Definitions for Illuminating Engineering</i> (RP-16-96) ♦ other IESNA publications 	<p>Illuminating Engineering Society of North America (IESNA) 120 Wall Street, 17th Floor New York, NY 10005-4001 Phone: 212-248-5000 Fax: 212-248-5017 or 5018 Internet: iesna.org</p>

References Related to Highway Illumination

Publication	Source
<ul style="list-style-type: none"> ◆ <i>Recommendations for the Lighting of Roads for Motor and Pedestrian Traffic</i> (CIE 115-1995) ISBN 3 900 734 59 3 ◆ <i>Road Lighting Calculations</i> (CIE 140-2000) ISBN 3 901 906 03 7 ◆ <i>Guidelines for Minimizing Sky Glow</i> (CIE 126-1997) ISBN 3 900 734 83 6 ◆ <i>Guide for the Lighting of Road Tunnels and Underpasses</i> (CIE 88-1990) ISBN 3900 734 259 ◆ Other CIE publications 	<p>The International Commission on Illumination (CIE) CIE Central Bureau Kegelgasse 27, A-1030 Vienna, Austria</p> <p>Internet: http://www.cie.co.at/cie e-mail: ciecb@ping.at</p>
FAA Advisory Circular AC 70/7460-1K, "Obstruction Marking and Lighting"	Federal Aviation Administration Internet: http://www2.faa.gov/ats/ata/ai/index.html
FAA Advisory Circular AC 70/7460-2K, "Proposed Construction or Alteration of Objects that may Affect the Navigable Airspace"	Federal Aviation Administration Internet: http://www2.faa.gov/arp/anm/services/safety/AC_70-7460-2K.pdf
Title 43, Texas Administrative Code, Section 25.11, "Continuous and Safety Lighting Systems"	Office of the Texas Secretary of State Internet: http://www.sos.state.tx.us
Texas Health and Safety Code, Chapter 425, "Regulation of Certain Outdoor Lighting."	Texas Legislature Internet: http://www.capitol.state.tx.us/statutes/he/he0042500.html
various electrical standards	Underwriter's Laboratories Northbrook Division, Illinois Customer Service 333 Pfingsten Road Northbrook, IL 60062-2096 USA Phone: 847-407-1395 Internet: http://www.ul.com
various electrical standards	NEMA 1300 North 17th Street Suite 1847 Rosslyn, VA 22209 Phone: 703-841-3200 http://www.nema.org

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Section 2

Responsibilities

Introduction

This section outlines the responsibilities of TxDOT divisions and districts in regard to highway illumination.

Traffic Operations Division

The Traffic Operations Division (TRF):

- ◆ prepares policies, procedures, and standards for electrical and illumination systems
- ◆ develops and maintains standard lighting agreement forms
- ◆ reviews and processes plans, specifications, and estimates (PS&E) for electrical and illumination projects
- ◆ assists districts with design, construction, and maintenance problems associated with electrical and illumination systems
- ◆ reviews and approves shop drawings for high mast lighting assemblies (unless the district chooses to handle the matter)
- ◆ conducts electrical and illumination design training
- ◆ reviews lighting and electrical field changes
- ◆ assists districts with luminaire pole shop drawings and submittal review of electrical and illumination projects
- ◆ writes specifications for warehouse stock and for purchase requisitions for lighting equipment.

Bridge Division

The Bridge Division (BRG) reviews and approves shop drawings for high mast lighting poles (unless the district chooses to handle the matter).

Design Division

The Design Division (DES) reviews and forwards “Airway-Highway Clearance Form” (FAA 7460-1) to the Federal Aviation Administration (FAA), as stated in the *PS&E Preparation Manual*. DES also forwards submission and clearance paperwork to the districts. These FAA requirements are found in Advisory Circular AC 70/7460-1K, “Obstruction Marking and Lighting” and Advisory Circular AC 70/7460-2K, “Proposed Construction or Alteration of Objects that may Affect the Navigable Airspace.”

Districts

Districts:

- ◆ initiate, process, and retain lighting agreements with cities and counties when necessary
- ◆ review and approve shop drawings for standard illumination projects
- ◆ design lighting and electrical projects
- ◆ ensure local government compliance with lighting agreements
- ◆ construct electrical and illumination projects in accordance with plans
- ◆ maintain electrical and illumination systems
- ◆ operate electrical and illumination systems
- ◆ ensure that standard designs are compatible with and applicable to plans
- ◆ prepare and submit FAA Form 7460-1 “Airway-Highway Clearance Form” to DES as stated in the *PS&E Preparation Manual* (FAA requirements are found Advisory Circular AC 70/7460-1K, “Obstruction Marking and Lighting” and Advisory Circular AC 70/7460-2K, “Proposed Construction or Alteration of Objects that may Affect the Navigable Airspace”).

Chapter 2

Lighting Systems, Highway Eligibility, and Warrants

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Section 1

Overview

Introduction

This chapter describes the different lighting systems, which roadways are eligible for those systems, and the conditions that warrant each system.

Types of Lighting Systems

Title 43, Texas Administrative Code, Section 25.11 defines two basic types of roadway lighting systems — “continuous illumination” and “safety lighting.” The rules also describe instances in which continuous lighting may be classified as safety lighting. Subsequent sections of this chapter describe each of these types.

Eligibility and Warrants

The rules specify the types of highways eligible for the spending of state funds on each type of illumination system. The Texas Department of Transportation (TxDOT) can only install and maintain lighting systems on *eligible* roadways where the conditions *warrant* such installation.

Eligibility. Eligibility requirements for each type of lighting system are described in the relevant sections of this chapter.

Warrants. TxDOT uses criteria called warrants to justify the need for and expense of roadway lighting at eligible locations. To determine if an eligible location meets the relevant warrant, TxDOT assesses roadway conditions in terms of criteria called “cases.” These cases are coded for ease of reference. The code consists of either “CL” (for continuous lighting) or “SL” (for safety lighting) followed by a dash and a number (for example: CL-2 or SL-4).

When roadway conditions meet or exceed one or more of the relevant cases, then the roadway in question warrants the lighting — in other words, the warrant is met.

After the warrant is met, TxDOT may enter into a partnership agreement with the city or local government (if necessary) and program the financing.

Submitting Substantiating Data

Districts should submit data substantiating that warrants are met with the request for programming or financing to the Transportation Planning and Programming Division.

Process Summary

When a lighting system is proposed (by a local government, citizens, or TxDOT personnel), the district first determines the eligibility of the roadway. If the roadway is eligible, then the district assesses conditions to determine if the lighting system is actually warranted. Only after both eligibility and the warrant (warranting conditions) are established, can the district execute an agreement with the local government (if necessary) and proceed with design and installation. Figure 2-1 provides a flow chart of this process.

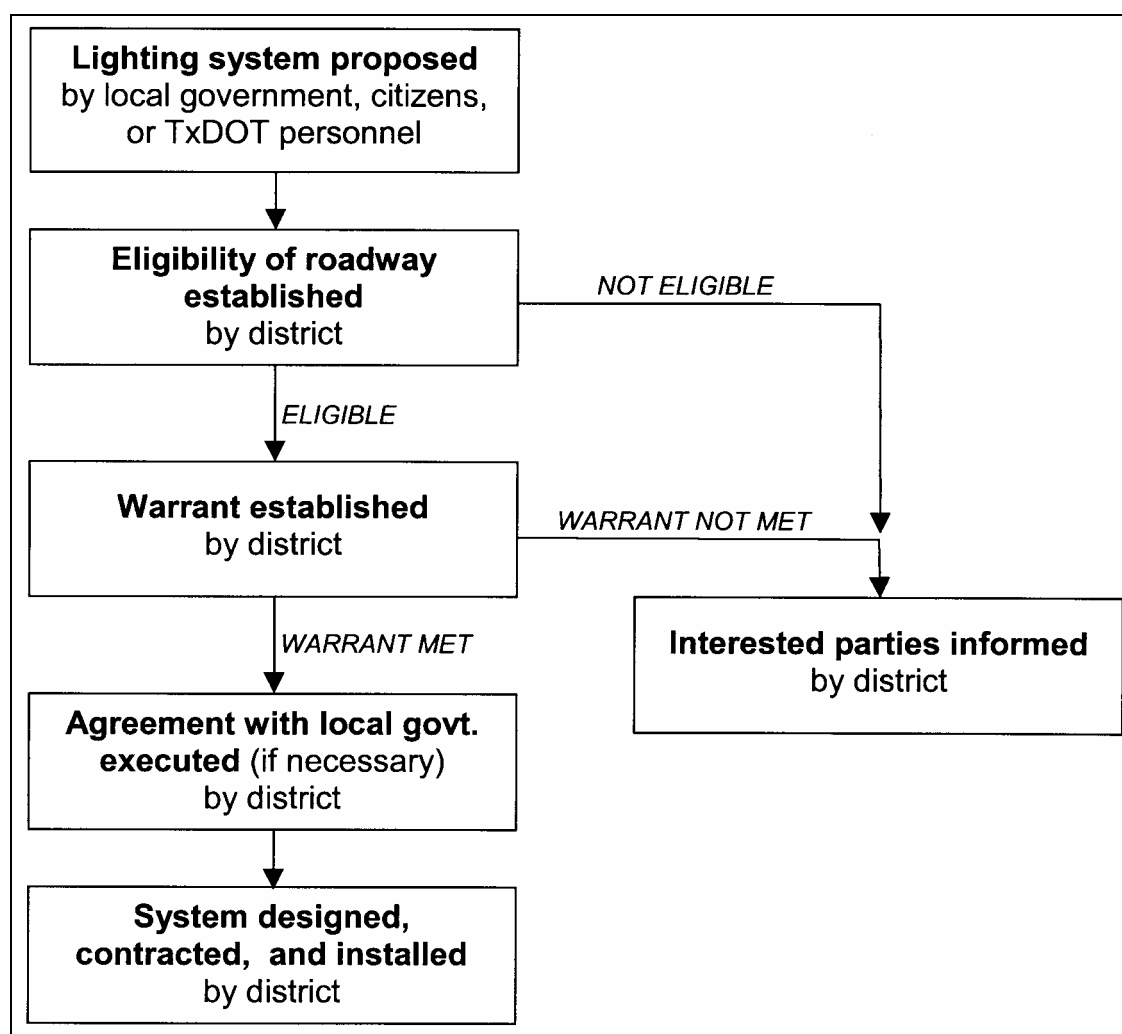


Figure 2-1. Highway lighting system process summary.

Section 2

Continuous Lighting

Description

A continuous lighting system provides relatively uniform lighting on all main lanes and direct connections and complete interchange lighting of all interchanges. Frontage roads are not normally continuously lighted by TxDOT.

The lighting units may be conventional luminaires or high mast assemblies or a combination.

Note: Continuous lighting requires the financial participation of the city (see Chapter 4, Section 2).

Eligibility

The following roadways are eligible for continuous lighting systems:

- ◆ urban freeways that are multi-lane divided facilities for which full control of access is provided
- ◆ multi-lane arterial highways with partial control of access where the following conditions exist:
 - access is provided to abutting property
 - at-grade crossings are provided at minor streets and roads
 - where grade separation structures are provided at major crossings of arterial highways, streets, and roads.

Warrants

Continuous lighting may be warranted under one of the conditions described in the following table.

Warranting Conditions for Continuous Lighting	
Case	Warranting Conditions
CL-1	Sections where the current average daily traffic (ADT) is 30,000 or greater.
CL-2	Sections where three or more successive interchanges are located with an average spacing of 1.5 miles or less and adjacent areas outside the right of way are substantially urban in character. <i>Note:</i> Interchanges must also qualify for safety lighting under one of Cases SL-4 through SL-7.
CL-3	Freeway sections of 2 miles or more passing through a substantially developed suburban or urban area in which two or more of the following conditions exist: <ul style="list-style-type: none">♦ local traffic operates on a complete street grid having some form of street lighting, parts of which are visible from the freeway♦ the freeway passes through a series of developments such as residential, commercial, industrial and civic areas, colleges, parks, terminals, etc. that include lighted roads, streets, parking areas, yards, etc.♦ separate cross streets, both with and without connecting ramps, occur with an average spacing of 0.5 miles or less, some of which are lighted as part of the local street system♦ the freeway cross section elements, such as median and borders, are substantially reduced in width below desirable sections used in relatively open country.
CL-4	Sections where the ratio of night to day crash rates is at least 2.0 times the statewide average for all unlighted similar sections, and a study indicates that lighting may be expected to result in a significant reduction in the night crash rate. <i>Note:</i> Because the ratio of night to day crash rates for a given section of roadway cannot always be statistically verified, this measure must be considered as an aid to design rather than an absolute rule. Engineering judgment should be exercised when using this warrant. See Title 43, Texas Administrative Code, Section 25.11, for additional information.

Specially Funded Projects

For specially funded projects, the project authorization must describe the ownership and maintenance responsibilities for the continuous lighting.

Section 3

Safety Lighting

Description

Safety lighting may be installed at any interchange, highway intersection, or other decision-making point or points of nighttime hazard. Safety lighting may be used to the extent necessary to provide for safety enhancement and the orderly movement of traffic.

There are three kinds of safety lighting: *partial interchange/intersection*, *complete interchange/intersection*, and *spot*. Which is used depends on the warranting conditions.

Partial interchange/intersection lighting covers:

- ◆ acceleration and deceleration lanes
- ◆ ramp terminals
- ◆ crossroads at frontage road or ramp intersections
- ◆ other areas of nighttime hazard.

Complete interchange/intersection lighting covers the limits of the interchange, including:

- ◆ main lanes
- ◆ direct connections
- ◆ ramp terminals
- ◆ frontage road or crossroad intersections.

Spot lighting is another kind of safety lighting. Spot lighting usually consists of one to five units intended to illuminate a nighttime hazard, such as sections with complex geometry or raised channelization.

For contracting purposes, all types of safety lighting are handled in the same manner.

Eligibility

Any designated highway or marked highway route is eligible for safety lighting. All highway intersections, interchanges, points of hazard, and decision-making points where such lighting would enhance the safe and orderly movement of nighttime traffic are eligible.

Warrants

Conditions warranting safety lighting vary depending on the type of roadway (freeway, expressway, or other designated on-system highway) and whether the proposed lighting is partial interchange, complete interchange, or spot.

Freeways and Expressways. For freeways and expressways, safety lighting may be warranted under one of the conditions described in the following table.

Warranting Conditions for Freeway and Expressway Safety Lighting

Type of Lighting	Case	Warranting Conditions
Partial Interchange/ Intersection	SL-1	Current average daily traffic (ADT) ramp traffic entering and leaving the freeway or expressway within the interchange area exceeds 5,000 for urban conditions or 3,000 for suburban conditions or 1,000 for rural conditions.
	SL-2	Current ADT on the through traffic lanes exceeds 25,000 for urban conditions, 20,000 for suburban conditions, or 10,000 for rural conditions.
	SL-3	Ratio of night to day crash rates within the interchange area is at least 1.25 or higher than the statewide average for all similar unlighted sections, and a study indicates that lighting may be expected to result in a significant reduction in the night crash rate. Engineering judgment should be exercised when using this warrant. See Title 43, Texas Administrative Code, Section 25.11, for additional information.
Complete Interchange/ Intersection	SL-4	Current ADT ramp traffic entering and leaving the freeway or expressway within the interchange areas exceeds 10,000 for urban conditions, 8,000 for suburban conditions, or 5,000 for rural conditions.
	SL-5	Current ADT on the crossroad exceeds 10,000 for urban conditions, 8,000 for suburban conditions, or 5,000 for rural conditions.
	SL-6	Existing substantial commercial or industrial development that is lighted during hours of darkness, is located in the immediate vicinity of intersection, or where the crossroad approach legs are lighted for 0.5 miles or more on each side of the intersection.
	SL-7	The ratio of night to day crash rates within the interchange area is at least 1.5 times the statewide average for all unlighted similar sections, and a study indicates that lighting may be expected to result in a significant reduction in the night crash rate. <i>Note:</i> Because the ratio of night to day crash rates for a given section of roadway cannot always be statistically verified, this measure must be considered as an aid to design rather than an absolute rule. Engineering judgment should be exercised when using this warrant. See Title 43, Texas Administrative Code, Section 25.11, for additional information.

(continued...)

Warrants (continued)

Other Designated On-System Highways. For other designated on-system highways, the cases described in the following table apply.

**Warranting Conditions for Safety Lighting
other than on Freeways and Expressways**

Type of Lighting	Cases*
Partial Interchange/Intersection	SL-2
	SL-3
Complete Interchange/Intersection	SL-5
	SL-6
	SL-7

*See previous table for explanation of warranting conditions.

Spot Safety Lighting. For spot safety lighting, case SL-3 applies for all types of roadways or it may be used at intersections or other areas where lighting will provide safer movement of traffic.

Continuous Lighting Classified as Safety Lighting

A continuous lighting system may qualify as a safety lighting system, provided all of the following conditions are met:

- ◆ the system is installed on a freeway with full control of access
- ◆ the freeway passes through unincorporated areas or through incorporated areas with municipal populations of less than 50,000 people according to the latest federal census
- ◆ the freeway has an average daily traffic (ADT) volume in excess of 70,000 vehicles
- ◆ a TxDOT study of the traffic volume or nighttime crash rate of the freeway indicates that continuous lighting would substantially improve traffic safety and the efficiency of nighttime traffic.

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Section 4

Bikeway and Pedestrian Way Lighting

Eligibility and Warrant

TxDOT may expend funds for continuous and safety lighting systems on bikeways and pedestrian ways on any segment of the state highway system and on any highway maintained by TxDOT.

Adjacent Roadway Lighting

When bikeway or pedestrian way lighting is installed, TxDOT may expend funds for lighting systems on the adjacent roadway to the same extent that lighting is provided for the bikeway or pedestrian way. Illumination levels should meet the requirements set forth in the AASHTO's *Informational Guide on Roadway Lighting* (see "References" in Chapter 1, Section 1, for information on obtaining this publication).

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Section 5

Systems Financed, Installed, and Operated by Other Agencies

TxDOT Policy

Local governments may finance, install, and operate illumination systems on those portions of designated or marked highway routes in cities and towns where such highways are not lighted by TxDOT.

Guidelines

TxDOT will cooperate with local governments in the consideration of such illumination systems. TxDOT personnel may assist and advise in the planning and design of such systems when requested by a local government.

Roadway lighting systems installed by local governments on a segment of the state highway system should meet all safety-related requirements under federal and state law and TxDOT functional manuals.

Cities must obtain the approval of the state for all proposals to install illumination. These proposals should be reviewed by TxDOT for compliance with pole placement guidelines. Such installations must be in accordance with municipal maintenance agreements and, in some cases, the city must obtain a utility permit from the district.

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Chapter 3

Master Lighting Plans

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Section 1

Overview

Introduction

The commitment to lighting roadway facilities is an immense responsibility. Part of the responsibility includes complying with Texas Health and Safety Code, Chapter 425, “Regulation of Certain Outdoor Lighting.” Among other things, this law requires that, for outdoor lighting installed, replaced, maintained, or operated using state funds, full consideration be given to energy conservation, reducing glare, minimizing light pollution, and preserving the natural night environment. Energy conservation includes reducing overall energy costs and resources used and may involve the use of lower wattage lights and timer switches. The full text of the law is available on the Internet at [<http://www.capitol.state.tx.us/statutes/he/he0042500.html>](http://www.capitol.state.tx.us/statutes/he/he0042500.html).

A master lighting plan can help in the fulfillment of this responsibility. District lighting engineers should work with municipalities and other concerned entities to develop master lighting plans.

Definition

A master lighting plan is a formal written arrangement between local governments and other entities within a municipal area to coordinate and standardize the design, operation, and maintenance of public lighting. Master lighting plans typically include lighting curfews and sophisticated monitoring systems (described in Section 4 and Section 5 respectively).

Benefits

The basic benefits of lighting include safety, beautification, and security for people and property. Additional benefits derived from a master lighting plan include:

- ◆ improved safety through the maximizing of resources
- ◆ a consistent image, reflecting the local culture and tastes
- ◆ nighttime linking of various sections of the city
- ◆ systems that better identify the nature of the site (residential versus “restaurant row” for example)
- ◆ better management of energy use
- ◆ tighter control of sky glow and light trespass
- ◆ aid in implementing lighting curfews
- ◆ increased public security (other concerns may warrant immediate turning on or off)
- ◆ coordinated maintenance
- ◆ easier coordination of maintenance specifications, such as poles, breakaway devices, and luminaires.

Section 2

Plan Development

Introduction

The master lighting plan development process should proceed as shown in the following table.

Master Lighting Plan Development Process

Step / Action	More Information
1. Contact the Traffic Operations Division (TRF)	TRF will assist in the development process.
2. Coordinate with other participants to set goals.	See following subheading for information on participants. See Section 3 for information on goals.
3. Consult with and consider the concerns of various groups having a stake in public lighting.	See “Groups Having Concerns about Lighting” later in this section.
4. Conduct a study to justify and determine the feasibility of the planned strategies.	See Section 4 for details on lighting curfews. See Section 5 for details on electrical and lighting management systems. See Section 6 for details on conducting studies.

Participants

The master lighting plan approach is a regional concept involving the following entities:

- ◆ TxDOT
- ◆ city
- ◆ county
- ◆ police
- ◆ traffic management centers or district offices
- ◆ fire, EMS, and other emergency agencies
- ◆ tunnel operators
- ◆ chambers of commerce (event coordination)
- ◆ parks (bike and pedestrian trails, fireworks, sports fields, etc.)
- ◆ the Federal Aviation Administration (near airports)
- ◆ the Coast Guard (near waterways).

Officials of these organizations should coordinate all publicly owned lighting systems by setting joint goals and laying out plans to achieve those goals.

Groups Having Concerns about Lighting

In addition to the participating entities, other groups will have concerns related to public lighting, and their concerns should be considered. These groups may include:

- ◆ citizens and property owners (some want a lot of lighting, some want none)
- ◆ retailers and other business
- ◆ tourists
- ◆ visitors
- ◆ parks and sports facilities (including spectator sports and participant sports such as driving ranges and softball).

Section 3

Goals of a Master Lighting Plan

Introduction

A master lighting plan should have five major goals:

- ◆ improved safety
- ◆ environmentally judicious use of resources
- ◆ judicious energy use
- ◆ attracting tourists, businesses, and nighttime activities
- ◆ planned maintenance.

Discussions of each of these goals follow under separate subheadings.

Improved Safety

Improved safety is the primary goal of public lighting. Public lighting affects motorists, cyclists, and pedestrians. Areas requiring public lighting include roadways, sidewalks, and signs. A master lighting plan can help improve overall safety by maximizing available resources and increasing management coordination. Maximizing resources means lowering operating costs of existing and new lighting systems, allowing the installation and operation of more lighting systems that operate only when needed.

Environmentally Judicious Use of Resources

“Environmentally judicious use of resources” refers to the consideration of citizen concerns. This consideration should encompass safety, security, aesthetic and architectural compatibility, creature comfort, sky glow, light trespass, glare, and visual clutter. These sometimes controversial concerns don’t necessarily fall into the category of “pollution,” in the sense that merely turning off the lighting would clean up any so-called pollution. Nevertheless, they are very important issues that are increasingly recognized as problems.

Some citizens want everything lit, some want nothing lit. While everyone will not likely be satisfied, the designer’s job includes consideration of the desires of the facility owner, city officials, and citizens as expressed in public hearings, local laws and ordinances, and other sources.

(continued...)

Environmentally Judicious Use of Resources *(continued)*

All outdoor lighting creates some degree of sky glow and light trespass. Sky glow is the scattering of light by moisture and dust particles in the atmosphere resulting in the halo on the horizon common over cities at night. Light trespass is the shining of light onto the property of another. For example, the shining of a street light into someone's bedroom window would be considered light trespass.

The evaluation of sky glow is highly subjective and fervently debated among those with a keen interest in the lighting as an art, a science, or a business interest, and those who wish to view the stars and a dark nighttime sky. The term "light pollution" was coined by those who obviously desire a reduction of nighttime lighting. Those who value the implementation of much nighttime lighting include advertisers, insurers, the safety conscious, and nighttime business operators. The consequences of implementing the opposite extremes of these views are epitomized by the area around McDonald Observatory and the area around Las Vegas, Nevada.

In the traffic engineering business, the safety of the traveling public is one of the most important factors. However, we cannot do all for safety and nothing for economy. The public cannot afford to light every street all night long.

A master lighting plan provides the opportunity for all interested parties to gain more of what they want by allowing for:

- ◆ reductions in light pollution (sky glow and light trespass) during curfew hours
- ◆ more lighting for traffic safety during hours of high use (through re-investment of energy savings into more extensive lighting systems)
- ◆ outdoor advertising before curfew hours
- ◆ increased energy savings.

Development of a master lighting plan allows all community and business desires to be investigated, respected, and implemented in balance. Of course, the plan cannot solve all arguments, but, it can be used as a tool to satisfy the purposes, desires, and needs of more people than is possible with simple on-all-night luminaire switching.

(continued...)

Environmentally Judicious Use of Resources (*continued*)

A wide variety of alternatives are available for outdoor lighting. Various environmental factors should be subjectively weighted for different situations. Some factors to consider include:

- ◆ purpose of the lighting
- ◆ source type
- ◆ degree of light cutoff
- ◆ light level
- ◆ mounting height
- ◆ ambient light levels (other lighting in the area)
- ◆ historical considerations
- ◆ area land use
- ◆ roadway classification
- ◆ pedestrian and cyclist use
- ◆ implementation of lighting curfews (see Section 4 of this chapter)
- ◆ effect on wildlife (some studies show that nighttime lighting may affect wildlife).

Review the following facility types and objectively weigh the benefits derived from lighting:

- ◆ urban freeways
- ◆ rural freeways
- ◆ central business district (CBD)
- ◆ arterial roadways
- ◆ collector roadways
- ◆ residential streets
- ◆ parklands and campgrounds.

Various guidelines of national and international lighting engineering and architectural groups may be consulted for reasonable limits and strategies to optimize lighting designs and limiting negative effects. The following table shows some of these groups.

Resources for Lighting Engineering Guidelines

Organization	Internet Address
The International Commission on Illumination (CIE)	http://www.cie.co.at/cie
The Illuminating Engineering Society of North America (IESNA)	http://www.iesna.org
The European Committee for Standardization (CEN)	http://www.cenorm.be

Judicious Energy Use

Important factors affecting energy use include light levels, lamp type, ballast type, and electrical systems quality. Lighting curfews can also help conserve energy (see Section 4 of this chapter for more information).

Attracting Tourists, Businesses, and Nighttime Activities

Public lighting intended to attract tourists, CBD businesses, and nighttime activities may include pedestrian, building façade, bridge or structure, landscape, and sign lighting. The intent is to provide a pleasing and attractive environment for nighttime activities.

Planned Maintenance

The purpose of planned maintenance is to prioritize maintenance schedules, organize contracts, and determine acceptable levels of service. Planned maintenance establishes consistent replacement products, coordinates traffic control setups, enhances the use of electronic monitoring, takes advantage of modern inventory systems, reduces troubleshooting of problems, reduces electrical hazards, and lowers overall costs. Larger systems are more likely to have a lighting engineer available to oversee the total process of design, installation, and maintenance, thereby allowing for replacement fixtures with suitable photometric, electrical performance, and aesthetic features. Under a master lighting plan, life cycle costs, life expectancy, and quality studies are enhanced, and the region will have more buying clout. See Section 5 of this chapter for a discussion of how modern electrical and lighting management systems can help with maintenance.

Section 4

Lighting Curfews

Introduction

Curfews for lighting involve the use of modern controls to turn off or dim selected parts of lighting systems as permitted by reduced traffic flow, favorable weather conditions, and other local conditions. Lighting curfews represent the active “operation” of the system, allowing for energy savings, greater flexibility in resource allocation, and reduction of light-trespass. However, officials implementing such options should be aware of consequences and conduct meaningful studies of costs and benefits.

Background

Studies on the effectiveness of roadway lighting have mixed results. It is generally accepted that, overall, continuous lighting reduces crashes by about 30 percent. The precise mechanism for the reduction of those crashes is not known. Currently it is not possible to translate surrogate measures, driver performance with targets, or other measures directly into a safety change.

Motor vehicle crash data for 2001 from the National Highway Traffic Safety Administration’s Fatality Analysis Reporting System (FARS) and the General Estimates System (GES) show that 90 percent of fatal and injury crashes that occur on the roadway, where lighting guidelines specify that light be placed, are multiple vehicle crashes. The number of overall crashes tapers off substantially after midnight on weekdays and after 4:00 A.M. on weekends. At these late hours, most of the crashes are single vehicle off roadway crashes for which lighting may not be likely to help, except possibly at decision making points such as ramp gores, intersections, and merge areas.

Warrants for lighting are empirically derived and based, among other things, on traffic volume. For lighting that has been installed based on traffic volumes, it may be reasonable to cut back the operation of the lighting system to complete interchange lighting or to partial interchange lighting when traffic volumes subside.

Studies show that crash rates can increase where systems are turned off or where every other luminaire is turned off. Alternate luminaire operation results in poor uniformity ratios. The issue of driver needs and safety versus conservation efforts should be closely examined when considering curfews. Some poorly conceived conservation efforts may contribute to excessive increases in traffic crashes and operational problems. These problems may actually result in higher overall costs.

Reasons for Curfews

Government entities around the world are considering lighting curfews for the following reasons:

- ◆ ***Low late-hours traffic volumes.*** AASHTO warrants for highway lighting are based, among other things, on traffic volume. When the primary reason that lighting is (or was) installed was due to high traffic volumes and high usage, which drops off in later hours of the night, it is reasonable to turn off or reduce the lighting after such drop-offs.
- ◆ ***To free up resources for greater overall safety.*** Lowering the operational costs of lighting systems by reducing electrical and maintenance costs through curfews may allow more lighting systems or other crash countermeasure to be installed, thereby reducing the overall nighttime crash rate within the jurisdiction of the master lighting plan.
- ◆ ***Technology now practical.*** Modern controls technology now allows control of individual luminaires or systems of luminaires at reasonable costs.
- ◆ ***Positive study results.*** Recent studies show that light dimming and turn-off curfews are viable options for management of public lighting systems, including roadway lighting. Although past studies showed unfavorable increases in traffic crash rates because of turning off lighting, these studies were performed on systems where the lighting was turned off or partially turned off for the entire nighttime period.
- ◆ ***Energy savings.*** Energy costs are high.
- ◆ ***Sky glow issues.*** Sky glow issues are of increasing importance to citizens.

Considerations Before Implementation

Special events, weather, and other local considerations should be included in the decision to implement lighting curfews. Implementation of curfews should occur through traffic management centers and should be monitored to gain experience as to the best operational procedures.

The following excerpts are from FHWA/RD-86/018: “Reduced Lighting During Periods of Low Traffic Density.” When considering lighting curfews, the complete report should be read, while realizing that it dates from August 1985. Modern crash data should be analyzed.

In part, FHWA/RD-86/018 states:

Over 50 percent of all motor vehicle fatalities occur in darkness even though only 25 percent of all travel occurs at night. This over representation has been used as a justification for installing fixed roadway lighting on many highways. However, research that has attempted to determine the effect of such fixed lighting on frequency and severity of night accidents appears to be mixed, such frequencies and severities being dependent on a host of geometric and traffic factors including the volume of traffic utilizing the road, how such volume is related to the road’s capacity, and the complexity of the driver’s visual search task.

(continued...)

Considerations Before Implementation (*continued*)

During the past decade, several highway agencies have switched off roadway lighting during periods of energy shortages to reduce maintenance and operating costs. However, quite often such lighting was restored when nighttime accidents increased. One fundamental problem with these light reduction techniques was that lighting was reduced or eliminated during the entire nighttime period, rather than only when traffic volume was low.

By providing full lighting during periods when volumes are high and the roadway operates near capacity and providing reduced lighting as the traffic decreases, the potential exists for realizing considerable energy savings while still providing the benefits of full lighting at locations (e.g., interchanges) and at times (i.e., high volumes) where driver decision-making is the most critical and the greatest visibility is required.

From a safety standpoint there is a definite reduction in (simulated) hazard detection performance, which theoretically implies some reduction in safety. This implied reduction in safety is statistically significant for all off and one side only lighting tactics, but not statistically significant for the dimmed tactics and the every other off tactic. Unfortunately, it is not possible at this time to quantify the exact decrease in safety in terms of the frequency of nighttime accidents, the night accident rate, or the night-to day accident ratio. Only an evaluation of long term installations can address this issue (see following discussion of further research needs).

Reduced freeway lighting tactics normally should not be implemented before about 11:00 P.M. in most urban areas, since traffic density typically remains relatively high until that time. Regularly scheduled sports events and other large traffic generators could change this time to a later hour, while cities with little or no evening activity might allow an earlier light reduction.

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Section 5

Electrical and Lighting Management Systems

Introduction

Master lighting plans allow for full benefits to be derived from modern electronic monitoring and control systems known as electrical and lighting management systems (ELMS). This technology can help detect lighting problems more quickly and accurately than traditional methods. The maximum benefit is most likely realized when the technology is applied across the entire lighting infrastructure within a local authority's inventory. Remote monitoring technology can modernize the management, operation, and maintenance of the street lighting infrastructure. Current methods used to monitor and control street lights are often underdeveloped and generally in need of modernization.

Cost

The costs of introducing the technology are difficult to estimate without significant evaluation, and this has led to concerns over initial investment costs, running costs, and anticipated payback on investment. It is important that such evaluations consider a whole system approach and also how remote monitoring might be progressively used and specified for new lighting schemes and for installations requiring additional or extraordinary monitoring and control.

Benefits

The benefits of ELMS are outlined in the following table.

Benefits of ELMS

Benefit	Explanation
More efficient contract management	Contracts can be written to pay for maintenance by the month instead of by each part repaired or replaced. Percent of luminaires burning can be verified electronically through ELMS, thus reducing contract management costs.
Improved electrical safety and reliability	ELMS provides for ground fault detection and notification of system malfunction.
Energy savings	Energy saving lighting curfews are facilitated through remote or automatic control of lighting systems.
Reduced maintenance costs	ELMS facilitates better advance knowledge of problems, parts needed, and types of personnel needed. This results in better overall contractor information and supervision of maintenance work.
Reduced life cycle costs	ELMS can provide the information and documentation needed to write better specifications and modify approved products lists, thus lowering maintenance costs and improving reliability.

(continued...)

Benefits (continued)

The recent avalanche of technical advances is about to bring a wave of new technologies to organizations that operate and maintain street lighting systems. If used smartly, these technologies have the potential to improve service quality, lower maintenance costs, increase productivity, and conserve energy. But the implementation of new technologies also holds risk because of technical and commercial complexities. The key to reducing this risk is to make the new technologies compatible with existing systems, and to ensure that the systems of different suppliers are interoperable.

Master lighting plans and ELMS allow coordination, through the traffic management centers, of all interested subjects and parties including cities, department of transportation personnel, police, special events, traffic management, state and local ordinances, landscape lighting, landscape installation (especially trees), landscape maintenance, pedestrians, cyclists, and central business district interests.

Benefits of ELMS Standardization

Interoperability and compatibility standards for ELMS results in four significant benefits, as outlined in the following table.

Benefits of ELMS Standardization	
Benefit	Explanation
Reduction in the complexity of integrating systems	This translates into lower risk of implementation delays and fewer resources required for system installation and introduction.
Creation of more open and competitive market	Proprietary technologies tend to lock buyers into single-source supply arrangements. Such arrangements give the incumbent supplier undue leverage in future purchases and make substitution of non-performing suppliers expensive. Standardization discourages this tendency.
Allowance for the mixing of systems from different suppliers	Various systems have their own strengths and weaknesses, given the differing situations in which they are used. If a buyer wishes to implement a system with “best of breed” components, then interoperation and compatibility between these components make that possible.
Evolution through open participation in which all views are considered	Due process through a public forum ensures validation and utility of the underlying technologies.

Interoperability and compatibility standards lead to a more competitive environment for suppliers. However, suppliers benefit from standards as well. In general, buyers are suspicious of single-source market conditions, and therefore simply delay purchases until a competitive environment has evolved. History has shown that the establishment of standards accelerates adoption of new technologies and causes the market to expand more rapidly.

Section 6

Conducting Studies

Introduction

Before developing a master lighting plan, a study should be conducted by traffic and lighting engineers familiar with lighting design standards, warrants for lighting, sky glow and light trespass issues, lighting system maintenance, electrical systems, traffic crash studies, and lighting controls. The study is needed for the following reasons:

- ◆ to determine how the various lighting systems can best be optimized and coordinated
- ◆ to justify the implementation of lighting curfews
- ◆ to justify expenditures for technological improvements such as ELMS.

This section describes the recommended scope of such a study. Generally, the study should cover:

- ◆ the electrical system
- ◆ the purpose of the lighting system
- ◆ benefits and effects of curfews and dimming
- ◆ traffic studies
- ◆ surrounding land use and surrounding lighting
- ◆ security concerns
- ◆ sky glow and light trespass issues
- ◆ community goals
- ◆ coordination with navigation authorities
- ◆ traffic management interaction
- ◆ controls
- ◆ curfew monitoring
- ◆ ELMS Implementation
- ◆ coordination with roadway maintenance and construction activities
- ◆ budget.

Discussions of each of these items follow under separate subheadings.

Electrical System

The study should evaluate electrical energy use and the potential for savings. This should include an assessment of the age, leakage current, and overall condition of the system.

Purpose of Lighting System

Determine the purpose of the lighting system. If the lighting was installed to improve safety because of high traffic volumes, it might be reduced to complete interchange lighting or partial interchange lighting after normal traffic volumes subside. Likewise, if safety during periods of high pedestrian traffic is the primary purpose of the lighting, it could be reduced or turned off after the pedestrian traffic subsides or is not expected.

Continuous roadway lighting is not expected to eliminate nighttime crashes nor can curfews be blamed for causing crashes. The precise effect of lighting roadways is not known. Continuous lighting has generally been shown to lower crash rates from 20 to 60 percent. Consider partial interchange lighting, which provides lighting only at decision making locations such as intersections and ramp gores where most crashes occur. Remember, the only required nighttime lighting is that of automobile headlamps.

The best use of resources may be to use fixed lighting on busy roadways and facilities during the time of their peak usage. This could free up funds now spent on lighting roadways in the early morning hours so they can be spent on lighting more roadways at peak traffic hours. In this way overall safety within the community is improved.

Determine how curfews would affect the historical, civic pride, and other extenuating circumstances relate to the lighting system.

Non-Roadway Lighting. Determine the purpose (need or enjoyment) and hours of use for non-roadway lighting systems for facilities such as:

- ◆ parks
- ◆ parking facilities
- ◆ landscapes
- ◆ historical sites
- ◆ aesthetic structure lighting
- ◆ hike and bike trails, etc.

Benefits and Effects of Curfews and Dimming

Determine the benefits and effects of curfews and dimming.

Dimming should be considered if light levels are higher than those required by AASHTO. In some instances lighting is installed at levels higher than the minimum required because of safety or work zones. It may be reasonable to dim this to only the required level after heavy traffic subsides. The same logic can be applied to dimming as is applied to curfews.

Traffic Studies

Assess the hourly nighttime traffic volumes and crashes.

Consider reducing continuous lighting to partial interchange lighting at the point during the nighttime hours when fatal crashes or severe injury crashes, analyzed over a three year period, is found to drop to half of the peak rate. Consideration may be given to the type of crashes and a study to determine if lighting is a factor in the specific traffic safety problem.

Surrounding Land Use and Surrounding Lighting

Assess the surrounding land use and surrounding lighting. Consider other area lighting that exists outside the control of the master lighting plan. Check the laws or ordinances governing surrounding lighting. Curfews for occupancy or use for parks, downtown areas, or other areas may already exist.

High levels of surrounding lighting may dictate that roadway lighting not be reduced depending on:

- ◆ proximity of such lighting to the roadway
- ◆ light levels
- ◆ glare and veiling luminance evaluations.

Normally roadway lighting should not be reduced to average light levels below that recommended by AASHTO when state or city owned lighting is provided on roadside sidewalks that is not also dimmed or turned off.

Determine the level of cooperation with private facilities that can be achieved.

Security Concerns

Assess security and vandalism concerns. Motion detectors used with incandescent or fluorescent lighting may be considered for use in non-roadway applications. Light levels and light source color may be a consideration for areas under video cameral surveillance.

Sky Glow and Light Trespass

Check for local light trespass and sky glow laws, restrictions, and ordinances.

Assess the system's sky glow and light trespass contributions. Determine community desires for sky glow and light trespass reduction (see Chapter 6, Section 4).

Community Goals

Conduct a survey of community goals for lighting.

Coordination with Navigation Authorities

Coordinate with air and sea navigation authorities when applicable. For example, lighting or lighted facilities may be used in some areas as landmarks for pilots.

Traffic Management Interaction

Determine the anticipated level of traffic management staffing. Dimming and curfew schemes can be better implemented if personnel are available to intercede with timely action such as turning lighting on at crash locations and programming for special events. This may require that traffic management centers be manned at all hours of the night.

Controls

Consider various algorithms or methods for control, including:

- ◆ control of selected areas, such as parks, central business district (CBD), residential streets, commercial streets, highways, freeways, parking lots, and rest areas
- ◆ on and off times
- ◆ the extent of the reduction of the lighting (reducing or extinguishing the lighting on interchange ramps, gores, and intersections is not recommended)
- ◆ degree of control (time clocks or modern electronic controls)
- ◆ modification of curfew schedules due to weather and special events.

Curfew Monitoring

Consider methods, need, and ability to monitor implemented curfews. Long-range monitoring of algorithms will help ensure optimum performance.

ELMS Implementation

Determine how and when the electrical and lighting management system (ELMS) may be implemented. See Section 5 of this chapter for information on ELMS.

Coordination with Roadway Maintenance and Construction Activities

Consider how dimming and curfew schedules should be adjusted to accommodate nighttime maintenance and construction operations so that motorists are alerted to unusual planned activities.

Budget

Consider how the master lighting plan relates to the following budgetary factors:

- ◆ how the plan would affect the budget for lighting installation and maintenance
- ◆ how the plan would affect the budget and methods for other traffic safety devices
- ◆ what the budget would be for installing controls.

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Chapter 4

Lighting Agreements

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Section 1

Overview

Introduction

All lighting projects within the corporate limits of a city or town involving state financing require an executed agreement between the local government and the Texas Department of Transportation (TxDOT). The agreement defines the responsibilities of each party in regard to construction, maintenance, and operation of the lighting system. The agreement should be executed before the project is let to contract.

Note: Luminaires mounted on traffic signal poles are covered by traffic signal agreements. See the *Traffic Signals Manual*, Chapter 5.

Continuous lighting requires the financial cooperation of the city, because the benefits derived extend beyond enhanced safety for motorists. Some of these benefits are improved aesthetics, lower crime rates, and a more conspicuous appearance for the city.

Initiation of Agreement

The design engineer should contact the city prior to designing the lighting system to determine the extent of lighting desired and to work out city participation. A lighting agreement, if necessary, should be initiated at that time.

Excess Costs

Sometimes participating cities or other local governments want amenities, qualities, or features that exceed the standard design equipment, systems, or practices of TxDOT incorporated into a lighting system. TxDOT will incorporate these desired items into the lighting system to the extent practicable, provided the local government furnishes all additional estimated funds in accordance with the terms of an escrow agreement between TxDOT and the local government.

Modification of Standard Agreements

If either party desires a modification to the standard agreement, the district should consult with the Traffic Operations Division (TRF) to make sure the modification is permissible.

City Ordinance or Resolution

As with any agreement entered into between a city and the state, an illumination agreement must be accompanied by an ordinance, passed by the elected governing council of the city, authorizing a designated city official to sign the agreement. If the city involved is a “home rule” city, whose charter authorizes the council to approve the execution of contracts by resolution, a resolution may be used in lieu of an ordinance.

Models of a city ordinance and resolution are included in the *Agreements Volume* of the Traffic Operations Collection.

Order of Commissioners Court

When the agreement is with a county, it must be accompanied by an order of the commissioner’s court, which authorizes the county judge to sign the agreement.

City (or County) Secretary’s Certificate

A completed city (county) secretary’s certificate must also accompany all agreements in order to verify the ordinance, resolution, or order. A model of a secretary’s certificate is included in the *Agreements Volume* of the Traffic Operations Collection.

Quotation on Plan Title Sheet

For blanket agreements, the following quotation from the agreement should appear on the title sheet of the plans with the city authorized signature:

Attachment No. XX-XX to special AGREEMENT FOR CONSTRUCTION, MAINTENANCE AND OPERATION OF CONTINUOUS HIGHWAY ILLUMINATION SYSTEM WITHIN MUNICIPALITIES, dated . The City-State construction, maintenance, and operation responsibilities shall be as heretofore agreed to, accepted, and specified in the Agreement to which these plans are made a part.

Also, the attachment sequence number (represented here as “XX-XX”) should be inserted into the quotation. Most districts use a yearly format for the sequence number, such as “Attachment No. 2-03” (where “2” is the second project let for the calendar year 2003).

Safety Lighting and Traffic Signal Installation

When safety lighting is installed by the state in an incorporated city as part of a traffic signal installation, a separate electrical service is not required. The safety lighting is considered incidental to the traffic signal installation and is covered by the traffic signal agreement or municipal maintenance agreement.

Safety Lighting Incorporated into a Continuous System

When a safety lighting system financed and installed by TxDOT is later incorporated into a continuously lighted urban freeway or expressway, the operation and maintenance cost will then be shared by TxDOT and the local government on the same basis as the cost of operation and maintenance of the continuously lighted section.

Default

If a local government defaults on any lighting agreement with TxDOT, TxDOT will discontinue any further funding of continuous lighting systems in that local government's jurisdiction, unless the executive director determines that such action would be inconsistent with the safety of the traveling public.

More Information

Chapter 3 of *Agreements Volume* of the Traffic Operations Collection contains more information on lighting agreements, including samples of the forms.

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Section 2

Continuous Lighting

Introduction

There are two kinds of standard agreements for continuous lighting systems — the “100 Percent Agreement” and the “50-50 Agreement.” Which agreement is used depends on whether TxDOT bears the entire cost of the system or shares the expense with a municipality.

100 Percent Agreement

The 100 percent agreement provides that TxDOT assumes the total cost of design and installation of the continuous lighting system, and that the local government assumes all cost of the subsequent operation and maintenance.

Full Title: Agreement for Construction, Maintenance, and Operation of Continuous Highway Lighting System(s) within a Municipality

There are two versions of the 100 Percent Agreement, identified as follows:

- ◆ SC(100) – CMO (100)(B) — referred to as the “100% Blanket Agreement”
- ◆ SC(100) – CMO (100)(SL) — same as above except restricted to specific limits (hence the “SL”) on the highway.

See Chapter 3 of the *Agreements Volume* of the Traffic Operations Collection for more information.

50-50 Agreement

The 50-50 agreement provides that TxDOT and the local government share equally the cost of the installation, operation, and maintenance of the continuous lighting system.

Full Title: Agreement for Construction, Maintenance and Operation of Continuous Highway Lighting System(s) within a Municipality (specific limits)

The 50-50 agreement is identified as follows: SC(50) – CMO (50)(SL).

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Section 3

Safety Lighting

Introduction

TxDOT bears the cost of installation, operation, and maintenance of safety lighting at interchanges, highway intersections, and points of nighttime hazard in both urban and rural areas, as traffic needs dictate.

If the safety lighting is within a municipality, TxDOT must enter into an agreement with the city. The type of agreement depends on whether TxDOT will maintain the system directly or contract with the city for maintenance.

Two Types of Agreements

There are two types of safety lighting agreements, both titled “Agreement for Construction, Maintenance and Operation of Safety Lighting Systems Within Municipalities.” They are distinguished as shown in the following table.

Safety Lighting Agreements	
Identification	Used When...
Blanket (SM, CP)	TxDOT maintains the system and contracts for power (blanket agreement).
Blanket (City, M & P)	TxDOT contracts with the city for both maintenance and power (blanket agreement).

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Chapter 5

Lighting Equipment

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Section 1

Overview

Overview

This chapter contains definitions and explanations of the equipment used in highway illumination.

Specifications

Current TxDOT highway lighting specifications are contained in both of the following:

- ◆ the *Standard Specifications for Construction of Highways, Streets and Bridges*
- ◆ Roadway Illumination Details (RID), High Mast Illumination Details (HMID), and Electrical Details (ED) contained in TxDOT's *Traffic Operations Standard Plans*.

These documents specify the various hardware components of a lighting assembly, together with the photometric and testing requirements of the lighting units and related equipment.

These documents are available from TxDOT. See “References” in Chapter 1, Section 1, for address.

AASHTO Guidelines

The American Association of State Highway and Transportation Officials (AASHTO) offers two publications relevant to lighting system design.

- ◆ *Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals* deals with structural materials and design. This book also covers the breakaway requirements for light poles.
- ◆ *An Informational Guide on Roadway Lighting* provides guidelines for the amount of light and the uniformity of light in roadway lighting systems. TxDOT design standards and warrants are derived from this guide.

These documents are available from AASHTO. See “References” in Chapter 1, Section 1, for address.

IESNA Guidelines

The *Lighting Handbook Reference and Application* published by the Illuminating Engineering Society of North America (IESNA) offers equipment guidelines. The publication is available from the publisher. See “References” in Chapter 1, Section 1, for address.

Non-standard Lighting

Non-standard lighting systems should meet AASHTO, IESNA, or International Commission on Illumination (CIE) requirements.

Section 2

Light Sources

Introduction

The light source (the lamp) is the device that actually converts electrical energy to visible light.

Light sources of interest in highway illumination design fall into two groups — incandescent lamps and electric discharge lamps. This section covers the various types of incandescent and electric discharge lamps.

Incandescent Lamps

The following table describes of two types of incandescent lamps along with usage notes for each.

Types of Incandescent Lamps

Lamp Type	Description	Usage
Common Incandescent	Consist of a tungsten filament enclosed in a glass envelope (the bulb) attached to a metal base. The bulb is evacuated and an inert gas (argon or nitrogen) is introduced into the bulb for longer life and better efficiency. For wattages less than 40, the filament usually operates in a vacuum, without the inert gas. A voltage applied to the filament through the base causes a current to flow through the filament which causes it to incandesce.	Low initial cost, but low efficacy (lumens per watt) and short lamp life.
Tungsten Halogen (quartz iodide)	Has a halogen, such as iodine, introduced into the lamp envelope. This lengthens lamp life and improves efficiency.	Tungsten halogen lamps are not normally used in highway lighting.

Electric Discharge Lamps

Electric discharge lamps produce light by the passage of an electric current through a vapor or gas instead of through a tungsten wire. The application of an electrical potential ionizes the gas, and permits current to flow between two electrodes located at opposite ends of the lamp. The electrons which comprise the current stream, or “arc discharge,” collide with the atoms of the gas or vapor, causing light to be emitted. Electric discharge sources have a negative resistance characteristic, and a transformer or ballast must be provided to limit the current.

Electric Discharge Lamp Types

Electric discharge lamps come in five common types. The following table provides descriptions of each type along with usage notes.

Types of Electric Discharge Lamps

Lamp Type	Description	Usage Notes
Fluorescent	Tubular bulb containing mercury. The mercury arc operating at a low vapor pressure produces ultraviolet light. The inside of the bulb is coated with a phosphor, and the ultraviolet light striking the phosphor causes visible light to be emitted.	Medium initial cost, long life, high efficacy (30 – 70 lm/w), but light varies with ambient temperature. Linear light source more difficult to control.
Induction Fluorescent	Same as fluorescent, except not tubular.	High efficiency (75 lm/w). Extremely long 100,000 hour life.
Mercury Vapor (MV)	Mercury arc in quartz arc tube. Operates at higher pressure and temperature than fluorescent. Arc produces visible light and some ultraviolet light. Far-ultraviolet filtered out by glass envelope. Clear lamps and phosphor-coated lamps available.	Phosphor-coated lamp used for sign lighting. High initial cost, long life, high efficacy (30 – 65 lm/w)*. Smaller light source than fluorescent.
High Pressure Sodium (HPS)	Arc in ceramic tube containing sodium and other elements. Provides light primarily in yellow spectrum but other elements provide light in blue, green, orange and red to improve color rendition. Requires a starting aid to provide pulse to start arc stream.	High initial cost, long life, high efficacy (45–150 lm/w)*, small light source.
Low Pressure Sodium (LPS)	Arc in long tubular glass envelope containing sodium only. Light is mono-chromatic yellow with poor color rendering.	High initial cost, moderately long life, high efficacy (145 – 185 lm/w)*. Light source hard to control photometrically.
Metal Halide (MH)	Similar to mercury lamp but contains various metal halides in addition to mercury. Excellent color rendering.	High initial cost, moderately long life, high efficacy (75 – 125 lm/w)*.

*The theoretical maximum efficacy is 683 lm/w. (lm/w = lumens per watt.)

High-Intensity Discharge Lamps

Of the electric discharge lamps, mercury vapor (MV), high pressure sodium (HPS), and low pressure sodium (LPS) are referred to as “high-intensity” discharge lamps. The following table compares their features.

Comparison of High-Intensity Discharge Lamp Features

Lamp Wattage and Type	Life (in hrs.)	Initial Lumen Output	Input Watts*
250 MV	24,000+	11,200	285
400 MV	24,000+	21,000	449
1000 MV	24,000+	57,000	1067
150 HPS	24,000	15,000	184
200 HPS	24,000	22,000	246
250 HPS	24,000	27,500	296
400 HPS	24,000	50,000	478
1000 HPS	24,000	140,000	1200
55 LPS	18,000	8,000	83
90 LPS	18,000	13,500	131
135 LPS	18,000	22,500	197
180 LPS	18,000	33,000	247

*Ballast input watts. For MV and HPS it is the average initial watts from actual tests. For LPS it is the average of initial and end of lamp life.

Best Choice

For normal roadway lighting (including high mast lighting) the high pressure sodium lamp is considered the best choice because of its efficiency, long lamp life, good color rendition, and small light source (which allows better photometric control and hence better utilization).

Induction fluorescent is suitable for low mounting heights and other special applications.

Spectral Energy Distribution Comparison

Figure 5-1 compares the color (spectral energy) distribution of a 400-watt mercury vapor lamp (Warm Deluxe) and a 400-watt high pressure sodium lamp (Lumalux). Note that the mercury vapor lamp performs better at the blue end of the spectrum, while the high pressure sodium lamp's light is concentrated in the yellow-orange range.

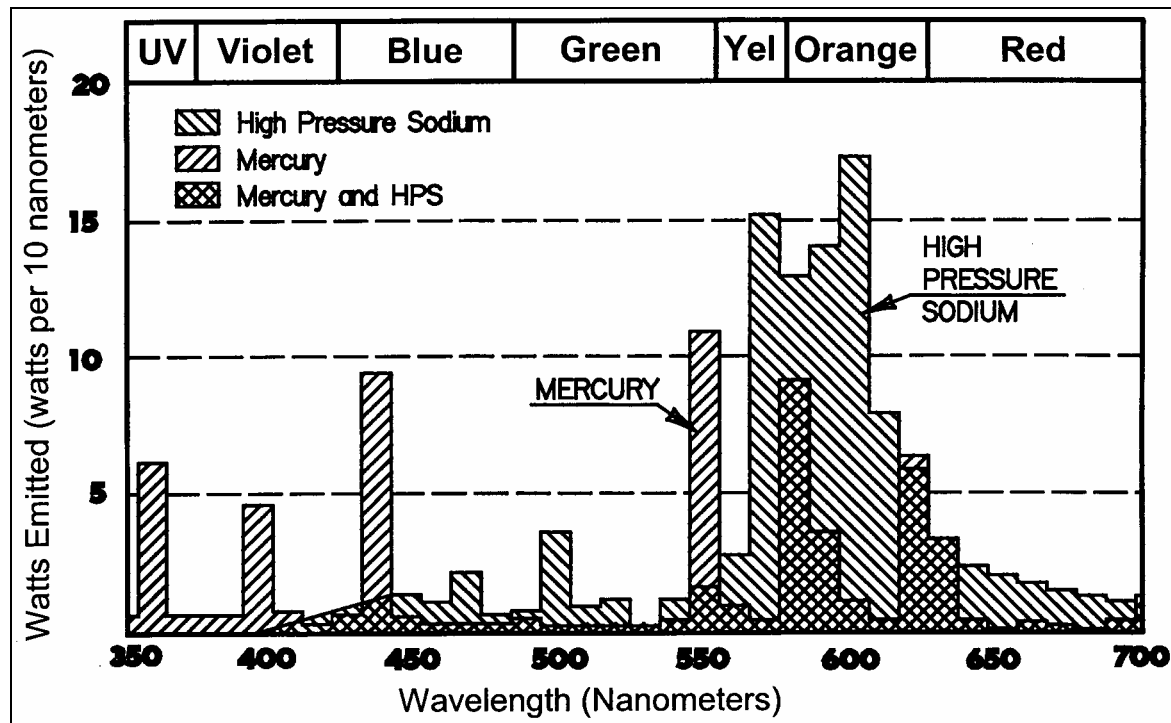


Figure 5-1. Comparison of 400-watt mercury vapor lamp (Warm Deluxe) and a 400-watt high pressure sodium lamp (Lumalux) color distribution.

Section 3

Luminaires

Introduction

The luminaire (pronounced *loom-in-air*) is the complete lighting unit (or fixture), including the light source, reflector(s), lens, and housing. This section describes some of the common types of luminaires and their uses.

Conventional Luminaires

Conventional roadway luminaires consist of cast aluminum housings with flat or sag glass lenses and polished aluminum reflectors. They are commonly called “cobra heads.”

These conventional units are usually mounted no higher than 50 feet. Typical sizes and mounting heights are:

- ◆ 250 watt HPS at 40 foot MH (mounting height)
- ◆ 400 watt HPS at 50 foot MH
- ◆ 150 watt HPS where lower mounting heights are necessary (such as near airports).

Mounting of Luminaires

“House side mounting” refers to the placement of luminaires between the curb and right-of-way line.

“Median mounting” refers to placement on open medians or medians with concrete traffic barrier.

See Chapter 6, Section 7, for complete discussions of house side and median lighting.

Cutoff

For roadway luminaires, the point on the ground directly below the light source is called the “nadir.”

Reduction of the luminous intensity (candlepower) in the upper portion of the light beam above nadir is required to control glare or reduce the amount of light falling off the right-of-way. Luminaires that feature this type of control are called “full-cutoff,” “cutoff,” and “semicutoff.”

The candlepower of luminaires designated as full-cutoff, cutoff, and semicutoff is limited at angles at 90 and 80 degrees from the nadir (see **Error! Reference source not found.**).

The following table shows the requirements for full-cutoff, cutoff, semicutoff, and noncutoff type luminaires.

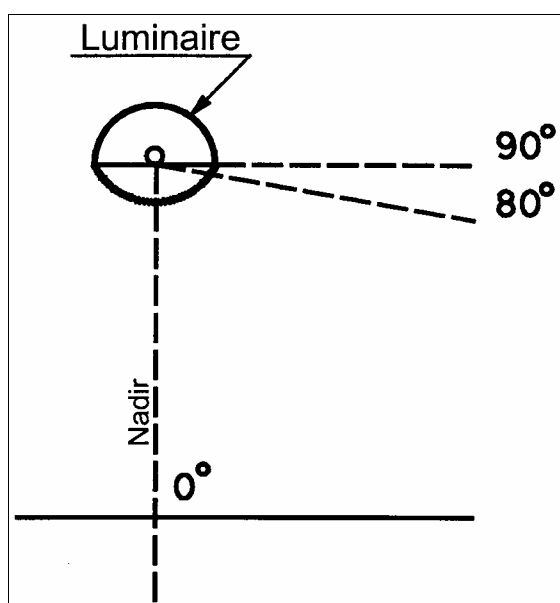


Figure 5-2. The candlepower of luminaires designated as full-cutoff, cutoff, and semicutoff is limited at angles of 90 and 80 degrees from the nadir.

Candlepower Cutoff Requirements for Different Luminaire Types

Luminaire Type	Percent of Total Candlepower at 90° from Nadir (Horizontal)	Percent of Total Candlepower at 80° from Nadir
Full-cutoff	0%	≤10%
Cutoff	≤2.5%	≤10%
Semicutoff	≤5%	≤20%
Noncutoff	No limitation in either zone.	

Note: In some cases the cutoff distribution may meet the requirements of the semicutoff, and the semicutoff may meet the requirements of the noncutoff.

Texas Health and Safety Code, Chapter 425, “Regulation of Certain Outdoor Lighting,” requires the use of cutoff luminaires (≤2.5% at 90° and ≤10% at 80°) for roadway lighting. The full text of the law is available on the Internet at <http://www.capitol.state.tx.us/statutes/he/he0042500.html>

Light Distribution Patterns

The Illumination Engineering Society (IES) writes many of the industry standard specifications for fixtures. The IES has designated several standard types based on their light distribution patterns. Figure 5-3 shows plan views of light distribution patterns for the basic types of conventional luminaires.

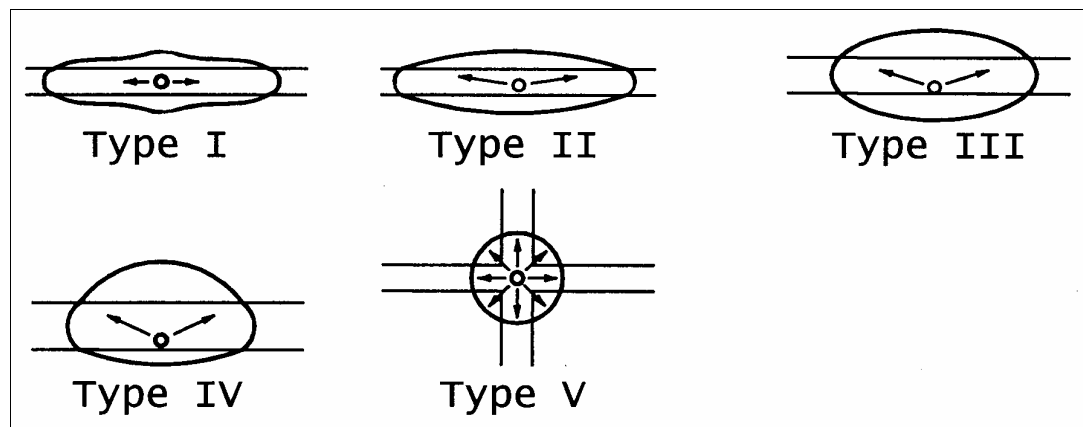


Figure 5-3. Plan views of light distribution patterns for basic types of conventional luminaires.

Typical roadway illumination fixtures that TxDOT uses are IES type MC-II and MC-III (medium-cutoff, type II and III distribution patterns).

Underpass Luminaires

Underpasses may require a special 150 watt HPS cobra head or induction fluorescent luminaires mounted on caps or special brackets.

Where structures are higher than 25 feet above the roadway, the 250 watt luminaire may be used.

High Mast Lighting

High mast lighting units are mounted at heights of 100 feet or more and use high pressure sodium light sources. The following table shows the three types of high mast lighting, their photometric characteristics, and their typical light sources.

Types of High Mast Lighting

Type	Photometric Characteristics
Symmetric Luminaires	Fixed position, cutoff luminaires provide a circular lighting pattern. Similar to IES Type V.
Asymmetric Luminaires	Similar to symmetric, except lighting pattern can be adjusted to provide elliptical or oblong pattern. <i>Note:</i> There are three types of asymmetric high mast luminaires: <ul style="list-style-type: none">◆ Type A — similar to IES Type II◆ Type B — similar to IES Type III◆ Type C — similar to IES Type IV.

Light Source. The typical light source for high mast lighting units consists of twelve 400 watt HPS lamps.

Section 4

Support Hardware

Introduction

Support hardware includes anything that physically supports the luminaire. Highway lighting hardware described in this section is covered in the *Standard Specifications for Construction of Highways, Streets and Bridges* under the following items:

- ◆ Item 610, “Roadway Illumination Assemblies”
- ◆ Item 611, “Removing Roadway Illumination Assemblies”
- ◆ Item 612, “Relocating Roadway Illumination Assemblies”
- ◆ Item 656, “Foundations for Signs, Traffic Signals, and Roadway Illumination Assemblies.”

Further information is also contained in the *Traffic Operations Standard Plans*, Roadway Illumination Details (RID).

See “References” in Chapter 1, Section 1, for information on obtaining these publications.

Roadway Illumination Assembly

The roadway illumination assembly is the complete assemblage of parts including the pole (or lighting standard), mast arms, fixtures, pole base, fuses, and connectors as specified by Item 610 as adopted by the Texas Department of Transportation.

Non-Breakaway Support

A non-breakaway support is a light pole that is rigidly mounted, usually remaining upright when hit by a vehicle. (See the discussions on the protection and placement of non-breakaway poles in Chapter 6, Section 7.)

Breakaway Support

A breakaway support is a light pole designed to shear easily under vehicular impact. The breakaway feature can be an aluminum transformer base, a frangible insert between pole base and foundation, a slip base, or other device. The breakaway support must meet current AASHTO and FHWA requirements. (See the discussions on use of breakaway poles in Chapter 6, Section 7. See the discussion of frangibility requirements in Chapter 9, Section 3.)

Transformer Base

The transformer base, made of cast aluminum, is bolted to a concrete foundation. The bottom flange of the pole is bolted to the top of the transformer base.

The aluminum is heat treated to make it “frangible,” so that the pole can break away from the base when struck by a vehicle.

Important: The structural strength of a breakaway luminaire pole depends on the pole and base combination. Bolt circle diameter, base plate thickness, and pole shaft diameter are key factors in determining the soundness of a breakaway luminaire pole. Refer to *Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals* (available from AASHTO — see “References” in Chapter 1, Section 1, for information on obtaining this publication).

Breakaway Connectors

Breakaway connectors are fused or unfused connectors in the base of light poles. Fuses are required in the “line” conductor (hot wire) of all light poles for circuit protection. When breakaway poles are used, the electrical conductors must also be breakaway. This is accomplished by using special pull apart fuse holders (breakaway connectors). In the case of breakaway poles, the neutral must also have this breakaway connector but should be unfused.

Note: When installing a breakaway connector, attach the female connector to the energized end of the wire. Leave the male connector with the wires traveling up the pole. This eliminates the possibility of someone coming into contact with the energized circuit.

Section 5

Other Equipment

Electrical Services

Electrical service equipment (or switch gear) includes the timber pole (or other support structure), weatherhead, meter, disconnect, fuses, breakers, panel-board, photocell, switches, contactors, and control transformer. Electrical service equipment is specified by Item 628 in the *Standard Specifications for Construction of Highways, Streets, and Bridges* and on the Electrical Detail (ED) Sheets in the *Traffic Operations Standard Plans*.

Other Electrical Equipment

For other electrical equipment, the Electrical Detail (ED) Sheets in the *Traffic Operations Standard Plans* are the standard. Items 618 through 628 in *Standard Specifications for Construction of Highways, Streets, and Bridges* are the specifications for electrical items. Many of the electrical details and requirements are in the *Standard Plans* instead of in the specification book, so the *Standard Plans* should be used together with the plans, specifications, and estimates (PS&E).

Other Lighting Equipment

Other lighting equipment is shown on the *Standard Plans* for roadway illumination, Roadway Illumination Details. Items 610 through 616 in *Standard Specifications for Construction of Highways, Streets, and Bridges* are the specifications for roadway lighting items. Many of the lighting details and requirements are in the *Standard Plans* instead of in the specification book, so the *Standard Plans* should be used together with the PS&E.

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Chapter 6

Lighting Design and Layout

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Section 1

Overview

Project Design Procedures

Highway illumination project designers generally follow the steps shown in the following table.

Highway Illumination Project Design Process	
Step	Action
1	Determine whether the lighting will be safety lighting or continuous lighting; then check to see to what extent lighting is warranted. (See Chapter 2.)
2	If the project is inside a city's limits, contact the city to see if they are willing to help finance continuous lighting for the project. (See Chapter 4.) Obtain the proper lighting agreement.
3	Determine what type of lighting to use (pole height, median or house side mounting or high mast). (See guidelines and standards throughout this chapter.)
4	Place lighting poles for the entire project. (See Section 6 and Section 7 of this chapter.)
5	Contact utility company to determine the type of service available and possible electrical service locations. (See Chapter 7, Section 2.)
6	Lay out circuits, keeping road crossings to a minimum, as jacking or boring escalates costs. (See Chapter 7, Section 3, "Circuit Design.")
7	Determine and label poles, length and size of wire, conduit, and duct cable. <i>Notes:</i> <ul style="list-style-type: none"> ◆ Show pole station number and offset from base line or edge line if applicable. ◆ For poles with similar offsets, offset can be shown by plan note. ◆ Electrical service numbers and light pole numbers are recommended.
8	Prepare sheet summaries and project summaries. (The project summary shows the items and quantities needed for the entire project. It is compiled from the sheet summaries and usually includes the electrical service data.)
9	If the project is inside a city limit, submit plans and title sheet with the proper quotation for city approval and signature. (For example, see Chapter 4, Section 1, "Quotation on Plan Title Sheet.")

Project Lead Time

For projects involving mainly illumination, an appropriate lead time must be allowed for the contractor to obtain the necessary materials. Typical lead time is 90 days for conventional lighting and 120 days for high mast lighting. This gives the pole manufacturers ample time to get shop drawings approved and poles constructed.

Joint Usage Encouraged

Joint usage of poles is encouraged to reduce roadside clutter and the number of fixed objects along the roadside. When lighting is provided at signalized intersections and when conditions permit, the luminaires should be mounted on the traffic signal pole.

Luminaires on Traffic Signal Poles

Luminaires on traffic signal poles should be powered from the same electrical service that powers the traffic signal.

Luminaire arms should be perpendicular to the roadway to be lighted.

Circuits Crossing Bridges

For circuits crossing bridge structures, use NEC type XHHW conductor in rigid metal conduit and show a junction box for grounding the metal conduit.

Railroad Crossings

For work involving railroad overpasses, consult the *Railroad Operations Manual* (Traffic Operations Collection) for required agreements with or notification of railroad companies.

Section 2

Illumination Levels

Introduction

This section describes TxDOT's standards for illumination levels for various roadway lighting situations.

References. See “References” in Chapter 1, Section 1, for information on acquiring the publications discussed in this section.

Continuous Lighting

The design method for continuous lighting of typical roadways should be the “illuminance” method. The light level for all applications should be as required by AASHTO's design guide: *Informational Guide for Roadway Lighting*. The “luminance” method requirements may be added or used in lieu of the “illuminance” requirements when deemed appropriate by the design engineer. The “luminance” method is preferred for tunnel lighting. Small target visibility (STV) should not be used.

TxDOT does not normally light frontage roads. Ramps and direct connectors should be lit to the same level as main lanes.

Safety Lighting

Safety lighting or “spot” lighting need not meet the light level requirements of continuous lighting; however, careful consideration should be given to the avoidance of excessive glare. Elements to consider include mounting heights, lamp wattage, and photometric distribution. The use of fixtures and mounting heights recommended in this manual and shown on the Roadway Illumination Details, as normally applied, will not create excessive glare. See Chapter 5, Section 3, for details on fixture requirements.

Tunnels

Tunnel lighting should be designed for asymmetric or pro-beam lighting systems only, except that tunnel transition zones may be counter-beam. Tunnel lighting should be designed in accordance with the above referenced AASHTO design guide or may be designed in accordance with the more comprehensive guidelines of CIE or IESNA.

Sidewalks and Bikeways

When installing lighting using state funds on sidewalks and bikeways (henceforth termed pedestrian lighting) along streets and highways, it is essential that the street be lit to the same level as the sidewalk or bikeway. This road lighting may be existing or may be added with the pedestrian lighting; it may be a part of the same lighting system or a separate lighting system.

This requirement is not intended to oblige cities or other entities to light the entire roadway if they desire some type of lighting along the roadway in accordance with Chapter 2, Section 5. However, the following points are generally accepted and should be considered:

- ◆ The reduction of veiling glare is beneficial.
- ◆ Veiling glare observed by a motorist is mitigated by increasing the illuminance of the roadway.
- ◆ Since lighting warrant CL-3 is used to establish that the expenditure of state funds for the mitigation of off-roadway lighting (veiling glare) would be sufficiently beneficial, TxDOT should not consider it reasonable to use state funds to build the very thing that needs mitigation.

The street and sidewalk or bikeway may be considered together as one element in determining minimum light level and uniformity. The contribution of both the pedestrian lighting system and the road lighting system may be considered for calculating light levels and uniformity of the sidewalk or bikeway and the roadway.

Other Types of Lighting

Other types of lighting systems (such as for rest areas, parking lots, central business districts, or temporary lighting in work zones) may be designed to meet the applicable requirements of AASHTO, IESNA, CIE, or other standards as deemed appropriate by the district engineer.

Additional Information

Additional information on light trespass may be found in CIE and IESNA publications. This information should be considered guidelines and not mandatory requirements.

Section 3

Plan Standards

Introduction

This section explains some of the standard practices used in TxDOT highway illumination plan layouts.

Scale of Plans

Generally, a scale of 1:100 provides plenty of detail for lighting layouts. Underpass lighting sometimes requires 1:50. Other special lighting systems, such as tunnel lighting, may require more detailed layouts.

Boring Logs

High mast lighting layouts should include soil boring logs. See the *Geotechnical Manual* (Bridge Collection) for details.

Standard Plan Symbols

TxDOT has developed standard illumination symbols to aid in plan preparation. Figure 6-1 and Figure 6-2 explain these symbols.

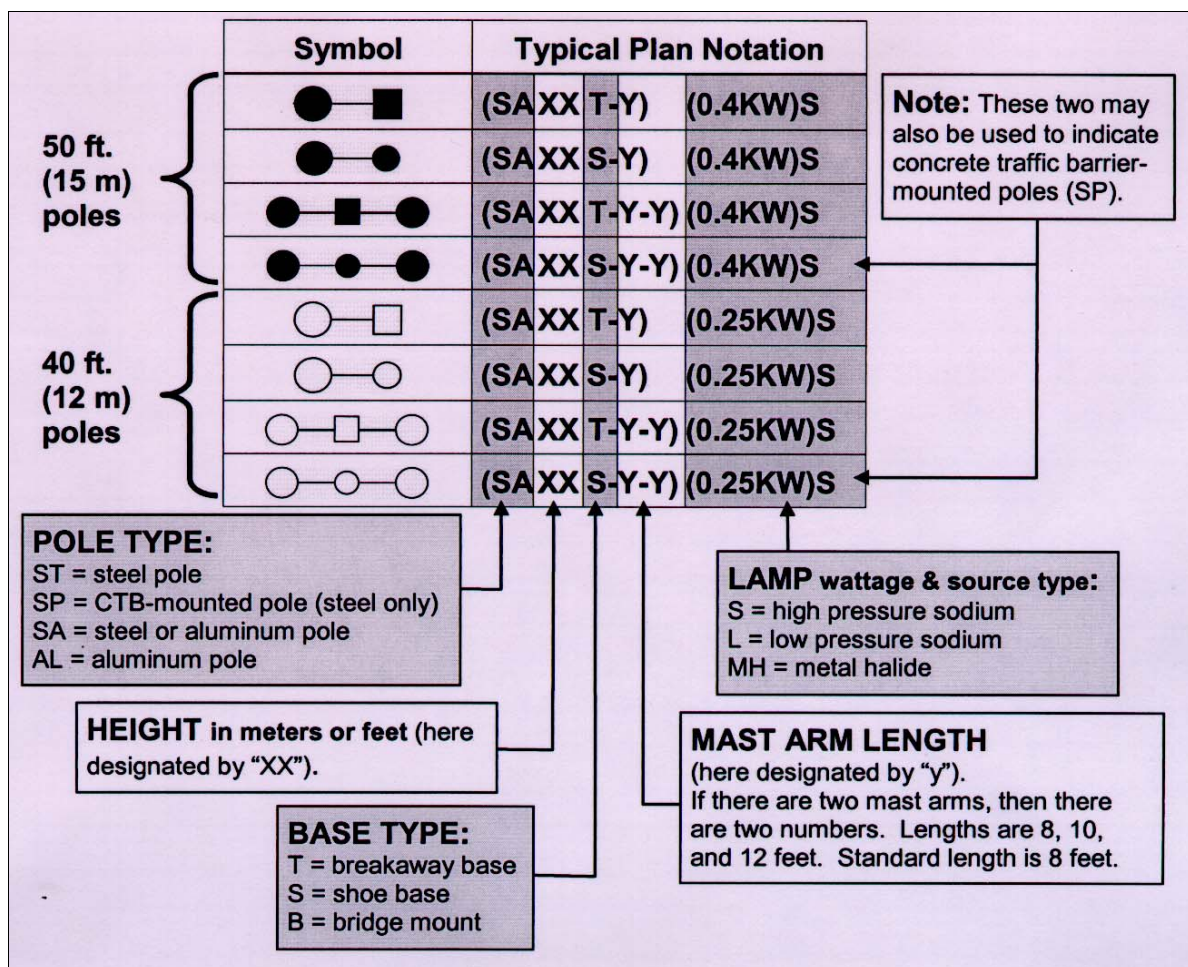


Figure 6-1. Standard symbols for light poles used by TxDOT in plan preparation. Note that breakaway transformer base poles are represented by a square, and non-breakaway (or "shoe base") poles are represented by a small circle.)

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Standard Plan Symbols *(continued)***Other Symbols:**






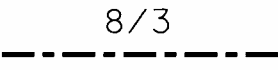

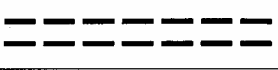
Symbol	Meaning
	High Mast Pole with fixture orientation arrow (used only on asymmetrical fixtures)
	Underpass Luminaire
	Electrical Service
	Ground Box, Below Grade
	Junction Box, Above Grade
	Duct Cable (size & number of conductors)
	Conductor in Conduit and Conduit Run Number (see conduit run table on plans)
	Conduit Bored Under Roadway

Figure 6-2. Other standard illumination symbols used by TxDOT in plan preparation.

Typical Plan Layout

Figure 6-3 shows a typical TxDOT illumination plan layout, illustrating the typical features, which include:

- ◆ a legend explaining the symbols used
- ◆ conduit and conductor run table
- ◆ table of roadway illumination assembly types and locations (including any special notes that pertain to each pole)
- ◆ plan sheet overall layout and scale
- ◆ sheet summary table
- ◆ electrical service data table.

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Typical Plan Layout (continued)

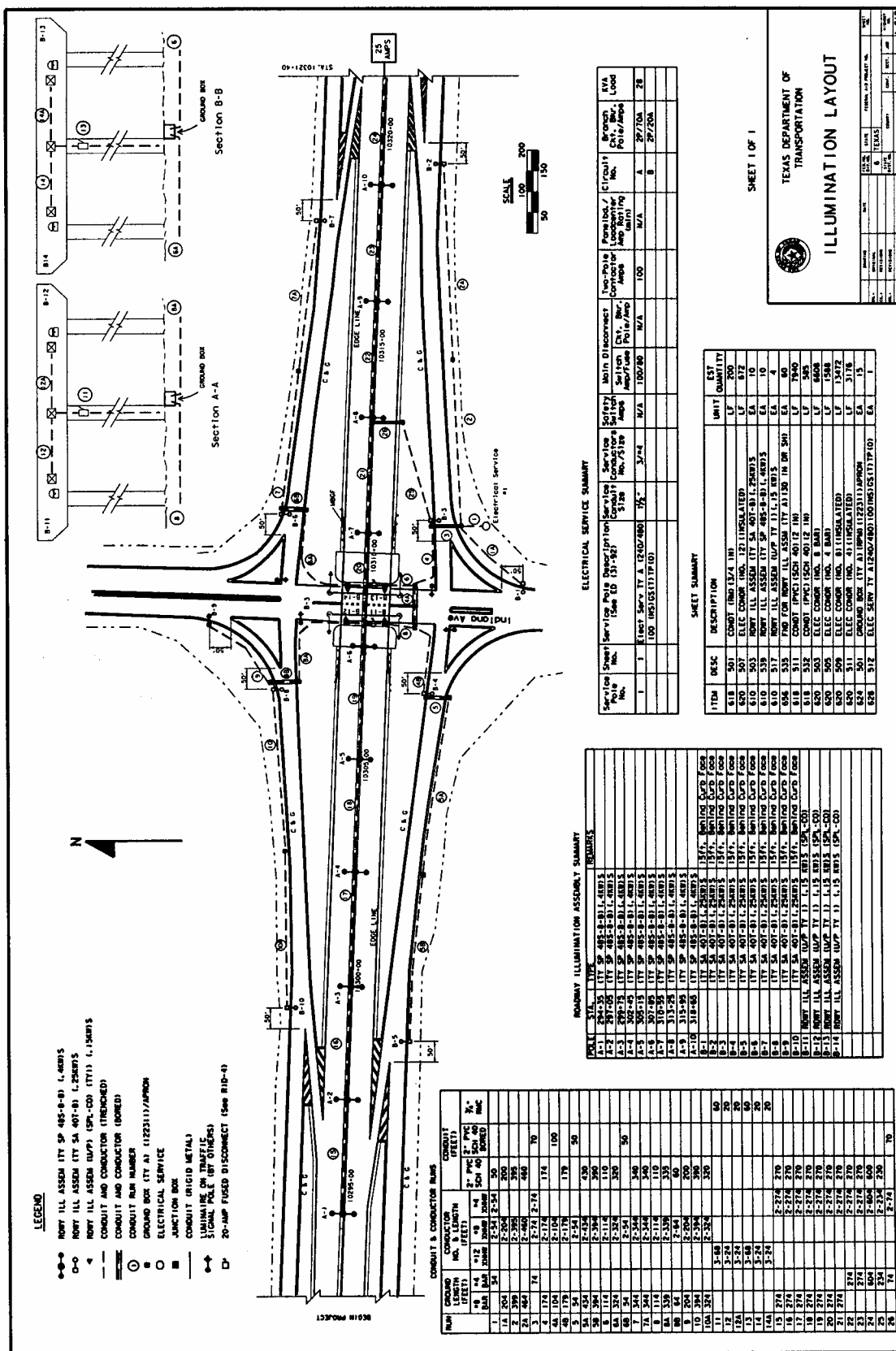


Figure 6-3. Typical illumination plan layout.

Section 4

Conventional vs. High Mast Lighting

Introduction

Conventional lighting systems are those using mounting heights of 50 feet or less. This description is used to differentiate between conventional mounting heights and high mast lighting, which uses mounting heights of 100 feet or more.

This section compares the advantages and disadvantages of conventional and high mast lighting and provides guidelines for deciding when to use high mast lighting.

Installation Costs

Installation cost comparisons between high mast and conventional lighting systems vary widely, depending on the application. High mast lighting for interchanges is frequently less expensive to install than conventional lighting, due to reduced complexity of conduit and conductor and the smaller number of fixtures and poles required. Outside the interchange, conventional lighting usually requires a smaller initial cost.

Maintenance Costs

Maintenance costs for the two types of systems differ greatly.

Conventional lighting requires the use of a bucket truck and frequently requires extensive traffic control, such as signs, cones, and lane closures. When poles are mounted on concrete traffic barriers (CTBs) or single slope concrete barriers (SSCBs), the inside lane usually has to be closed, resulting in significant traffic disruptions.

One or two persons with a pickup truck can usually perform maintenance on a high mast lighting system. High mast lighting may also eliminate the risks involved with having personnel working near high-speed traffic.

Some Deciding Considerations

Some important questions to consider when deciding whether to use conventional or high mast lighting are:

- ◆ Will lane closures be necessary for maintenance? What will be the effect on traffic?
- ◆ What is the initial cost difference?
- ◆ What is the maintenance cost difference? (When designing a lighting system, consider all maintenance costs, including costs incurred by other governmental bodies.)
- ◆ Would future upgrading of the roadway require relocating a conventional lighting system? Can a high mast system be installed that will not require relocation and that can provide construction lighting for future roadway projects?
- ◆ What is the proximity of airports and residential areas?

High Mast Systems Recommended

High mast lighting should be considered for most urban interchanges that qualify for complete interchange lighting and for tangent sections of freeways with initial average daily traffic (ADT) of 70,000 or greater where lane closure would be necessary for the maintenance of a conventional lighting system and where a study shows that substantial traffic flow disruptions would occur during such lane closures.

High Mast Systems and Light Trespass

High mast lighting should not be installed in areas where light trespass is an issue. This is generally areas where residential development is located directly along the highway right-of-way and pole placement is limited to the outside of the roadway. Special high mast designs should be considered to avoid light trespass, if high mast lighting must be employed. See Section 5 of this chapter for more information on light trespass.

High Mast Design and Layout

Layouts for high mast lighting are much more complicated than those for conventional lighting, since there are many different lighting fixtures and schemes available. The Traffic Operations Division (TRF) provides high mast illumination design assistance upon request. High mast lighting design procedure is beyond the scope of this manual.

Remember, high mast lighting layouts should include soil boring logs. See the *Geotechnical Manual* (Bridge Collection) for details.

Figure 6-4 shows a typical high mast plan layout for safety lighting.

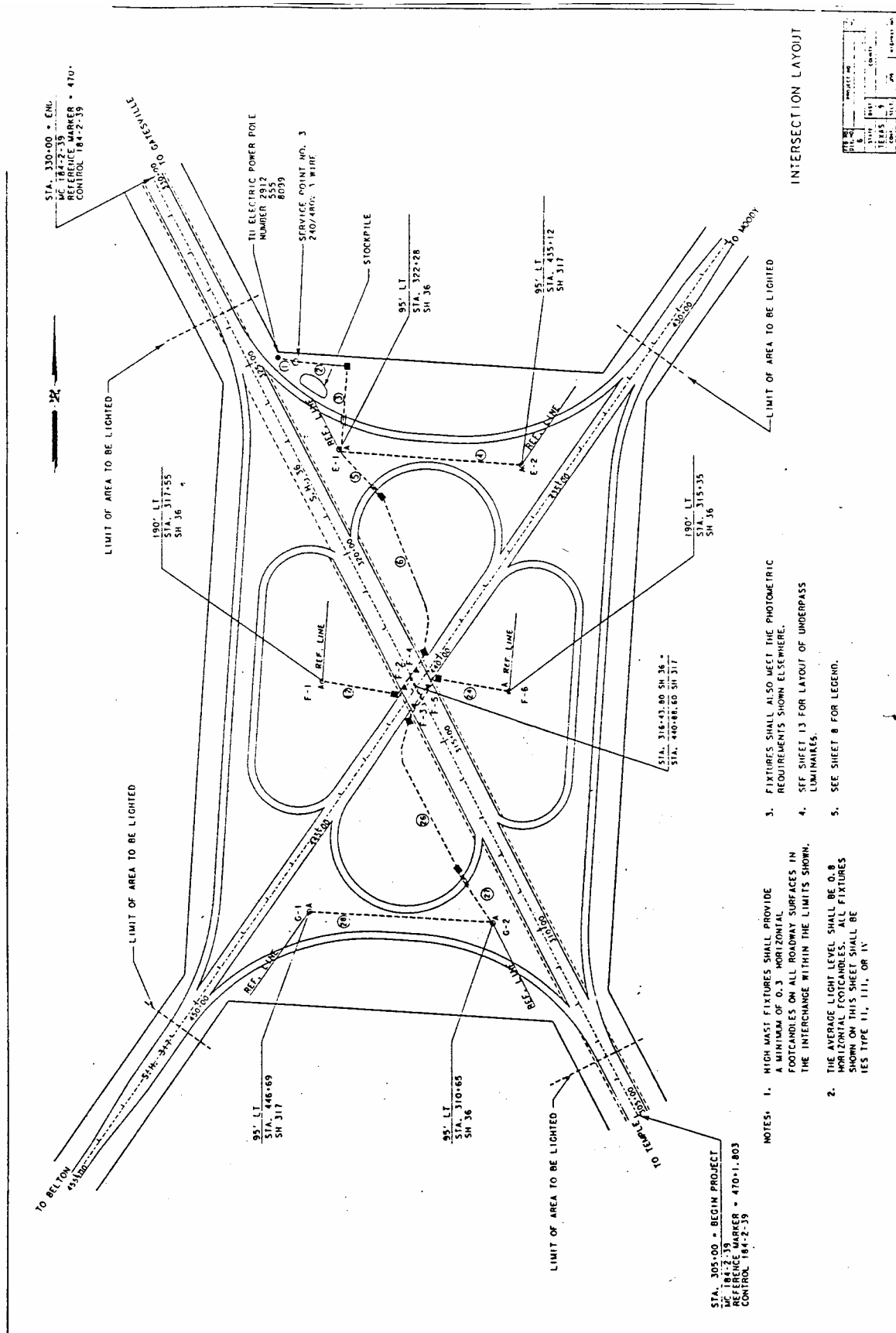


Figure 6-4. Typical high mast plan layout for safety lighting.

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Section 5

Glare and Sky Glow Issues

Introduction

Roadway lighting systems are coming under greater scrutiny from various sectors of the public. Issues such as glare, sky glow, and aesthetic lighting have achieved widespread attention and are open to criticism. Lighting designers should become familiar with these issues and be prepared to design lighting systems that meet required illumination levels, while also considering the environmental and aesthetic effects.

Communities are adopting lighting ordinances meant to reduce sky glow (popularly termed “light pollution”). Lighting designers should be on notice that this is a very important issue. Light emitted above the horizontal does not benefit roadway lighting, but it can contribute to glare and may be considered visual clutter. Many people consider sky glow undesirable and even offensive. This is an immensely important issue with the astronomical community, professional and amateur, and is particularly annoying when equally effective lighting systems can be designed that reduce or eliminate direct-up lighting.

Choice of Luminaires

Unless it is essential to have light aimed above the horizontal (as for building facades, landscapes, and central business districts, for example), non-cutoff luminaires should not be used for new roadway lighting. Improperly used non-cutoff luminaires may be considered a waste of energy.

Luminaires used for roadway lighting should at least be cutoff. Full cutoff should be considered first.

When emitting light above the horizontal is absolutely necessary and in accordance with Texas Health and Safety Code, Chapter 425, “Regulation of Certain Outdoor Lighting,” the designer should strive to keep the above-horizontal light as low as practical to accomplish the intended effect. This can be achieved by using lower wattage luminaires, by shielding, or by luminaire design.

Luminaire Modification

Adding glare shields to the existing roadway lighting luminaires of a continuous lighting system is generally not a good practice. Glare shields modify the photometric distribution of the luminaire and may cause an acceptable lighting system to no longer meet design standards. Luminaire photometrics are rarely measured with external shields installed, so the designer cannot know how a luminaire with glare shields will perform. A qualified lighting designer should investigate the effect of adding glare shields prior to their installation. It may be necessary to change the entire luminaire, rather than alter the photometric performance of existing luminaires.

Resources

Knowledge of this subject and implementation of design techniques to reduce or eliminate these problems enhances the public's perception of the professionalism of lighting designers and benefits citizens through a show of concern for neighbors and the complete aesthetic environment.

For further information on this subject, see:

- ◆ ANSI RP-8-00
- ◆ IESNA TM-10-99, "IESNA Technical Memorandum Addressing Obtrusive Light (Urban Sky Glow and Light Trespass) in Conjunction with Roadway Lighting"
- ◆ IESNA RP-33-99, "Lighting for Exterior Environments"
- ◆ CIE Report 126, 1997, "Guidelines for Minimizing Sky Glow."

Section 6

Spacing of Light Poles

Standard Spacing for Freeways and Complete Interchange Lighting

For freeways, poles (illumination assemblies) for conventional lighting should be spaced as shown in Figure 6-5.

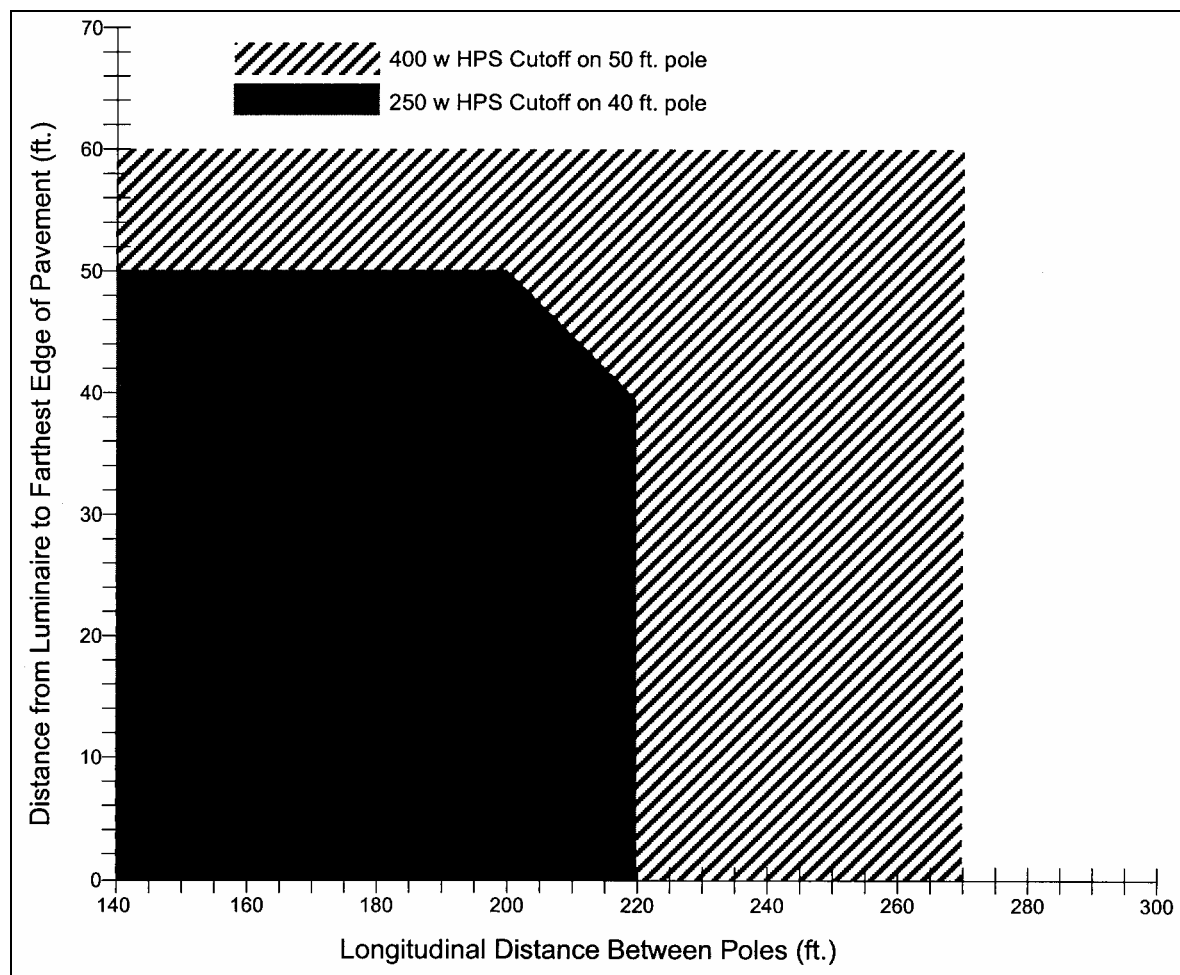


Figure 6-5. Recommended spacing for freeway and complete interchange lighting.

Standard Spacing for Roadways Other than Freeways

To determine the required illumination levels for roadways other than freeways, use *An Informational Guide for Roadway Lighting*, available from AASHTO (see “References” in Chapter 1, Section 1, for information on obtaining the publication). An illumination program capable of calculating luminance or illuminance levels is required to determine if adequate illumination levels have been achieved.

Merge and Diverge Lanes

For partial interchange lighting, the first light pole for merge and diverge lanes should begin at the end of the weave area and continue to within 50 feet of the painted gore, as shown in Figure 6-6.

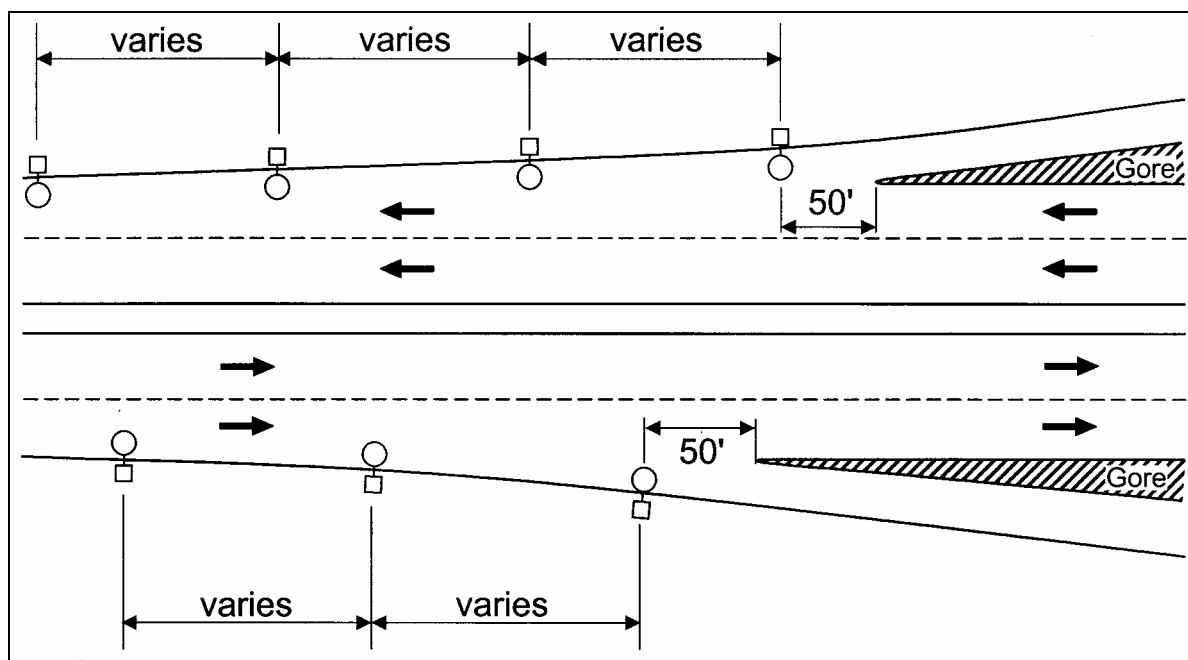


Figure 6-6. Typical placement for partial interchange lighting, 40 foot luminaire poles at merge and diverge lanes.

Lighting Near Overpasses

Poles supporting lighting for roadways beneath overpasses should be placed at least 20 feet from the overpass to reduce glare on the overpass.

Determining Mounting Height

Mounting height depends on the number of lanes to be lighted. The designer must use the mounting height that allows for adequate illumination levels. If proper lighting cannot be achieved with one pole, the designer should consider using additional poles to provide proper coverage.

Transition Lighting

Transition lighting is a technique intended to provide drivers with a gradual reduction in lighting levels and glare when leaving a lighting system. The use of Transition lighting is not generally recommended for TxDOT projects.

If transition lighting is used, the techniques for providing a transition are many and can be applied to all types of lighting systems with varying degrees of complexity.

For further information on transition lighting see:

- ◆ ANSI RP-8-00
- ◆ *Lighting Handbook Reference and Application*
- ◆ *An Informational Guide on Roadway Lighting*

See “References” in Chapter 1, Section 1, for information on obtaining these publications.

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Section 7

Pole Placement Guidelines

Introduction

This section contains guidelines for the placement of conventional lighting poles in relation to other roadway elements. These guidelines apply to all designated routes, whether the poles are installed by construction contract, state forces, municipalities, or others.

Clear Zone

This section contains references to the “clear zone” (also called the clear recovery area). The clear zone is provided along highways to allow vehicles veering off the travel lane opportunity for safe recovery or stopping. The clear zone width (always measured from the edge of the travel lane) depends on several factors, including:

- ◆ whether the surrounding area is rural or urban
- ◆ the functional classification of the highway
- ◆ the design speed
- ◆ average daily traffic (ADT).

The *Roadway Design Manual* contains a full discussion of the clear zone (Chapter 2, Section 6, Subheading: “Horizontal Clearance to Obstructions”) and provides the minimum and desirable widths for various roadways.

Note: Light poles should be offset at least 2.5 feet from the curb face, even if the clear zone is 1.5 feet. All pole offset dimensions shown in this section are measured to the pole centerline.

House Side vs. Median Mounting

“House side mounting” refers to the placement of luminaires between the curb and right-of-way line.

“Median mounting” refers to placement on open medians or medians with concrete traffic barrier.

Two Types of Poles

There are two types of poles used for conventional lighting: “non-breakaway” and “breakaway.” Non-breakaway poles are rigidly mounted, usually remaining upright when hit by a vehicle. Breakaway poles (described in Chapter 5, Section 4, under the heading “Breakaway Support”) are designed so that the base will shear easily on impact. The following table briefly explains the advantages and disadvantages of both types when struck by an errant vehicle.

Breakaway and Non-breakaway poles — Pros and Cons

Type of Pole	Advantage	Disadvantage
Non-Breakaway	Normally does not fall down and cause further damage to surrounding people and property.	Likelihood of greater injury to occupants and damage to vehicle.
Breakaway	Less likelihood of damage to impacting vehicle and injury to occupants.	Falling pole may be hazard to surrounding pedestrians, traffic, or property.

Breakaway Poles Preferred

Because of their respective advantages and disadvantages, both types of poles have appropriate uses. However, unless special circumstances exist, breakaway poles are preferred over the non-breakaway type.

When Not To Use Breakaway Poles

Circumstances that would preclude the use of breakaway poles include situations where they are more hazardous than a non-breakaway poles and situations in which the breakaway feature would be useless. Breakaway poles are not normally used if:

- ◆ substantial pedestrian traffic is a consideration in the area
- ◆ a falling pole could cause more damage than that caused by an automobile striking a rigid pole
- ◆ overhead electric lines are too close
- ◆ the pole is mounted atop a concrete traffic barrier
- ◆ the pole is mounted behind a metal beam guard fence (see following discussions on “Protection of Non-Breakaway Poles” and “Placement of Non-Breakaway Poles”).

Other considerations frequently come into play. The preceding list is provided only as an overview.

Protection of Non-breakaway Poles

When a non-breakaway pole is used inside the clear zone, it must be protected from traffic. Acceptable methods of protection include mounting the pole:

- ◆ on a concrete traffic barrier
- ◆ behind a metal beam guard fence or other non-yielding structure.

Curbs are not considered adequate protection for non-breakaway poles.

Placement of Non-breakaway Poles

Generally, non-breakaway roadway lighting poles may be used on the house side of roadways when placed outside of the clear zone or inside the clear zone when protected from impact.

Non-breakaway poles should be placed as close to the right-of-way line as lighting design and practicality permit. Wherever possible, non-breakaway poles should be placed among other nonyielding structures, to minimize the hazard.

If non-breakaway poles are used and are not protected, the poles must be outside the clear zone and as close to the right-of-way line as possible subject to good lighting design practice.

Non-breakaway poles mounted behind metal beam guard fence should be placed at least 2.5 feet behind the guard fence.

Remember, joint usage of poles is encouraged to reduce roadside clutter and the number of fixed objects along the roadside. When lighting is provided at signalized intersections and when conditions permit, the luminaires should be mounted on the traffic signal pole. Note that luminaires mounted on traffic signal poles should be powered from the signal electrical service.

Luminaires mounted on traffic signal poles should be oriented so that they are perpendicular to the centerline of the roadway being lighted.

Falling Area for Breakaway Poles

To understand the use and placement of breakaway poles, it is important to understand the concept of “falling area.” Research shows that most errant vehicles striking light poles are traveling at an angle less than 20 degrees from their original path and that light poles fall within one mounting height from the foundation along the direction of vehicle travel. A breakaway pole falls within $\frac{2}{5}$ (40 percent) of its mounting height in a direction perpendicular to and away from the lane in which the errant vehicle was traveling (see Figure 6-7). Therefore, to prevent knocked down poles from encroaching onto other traffic lanes, breakaway poles should be placed so that they have a falling area of at least $\frac{2}{5}$ of the mounting height behind the poles and one mounting height on the side of the pole.

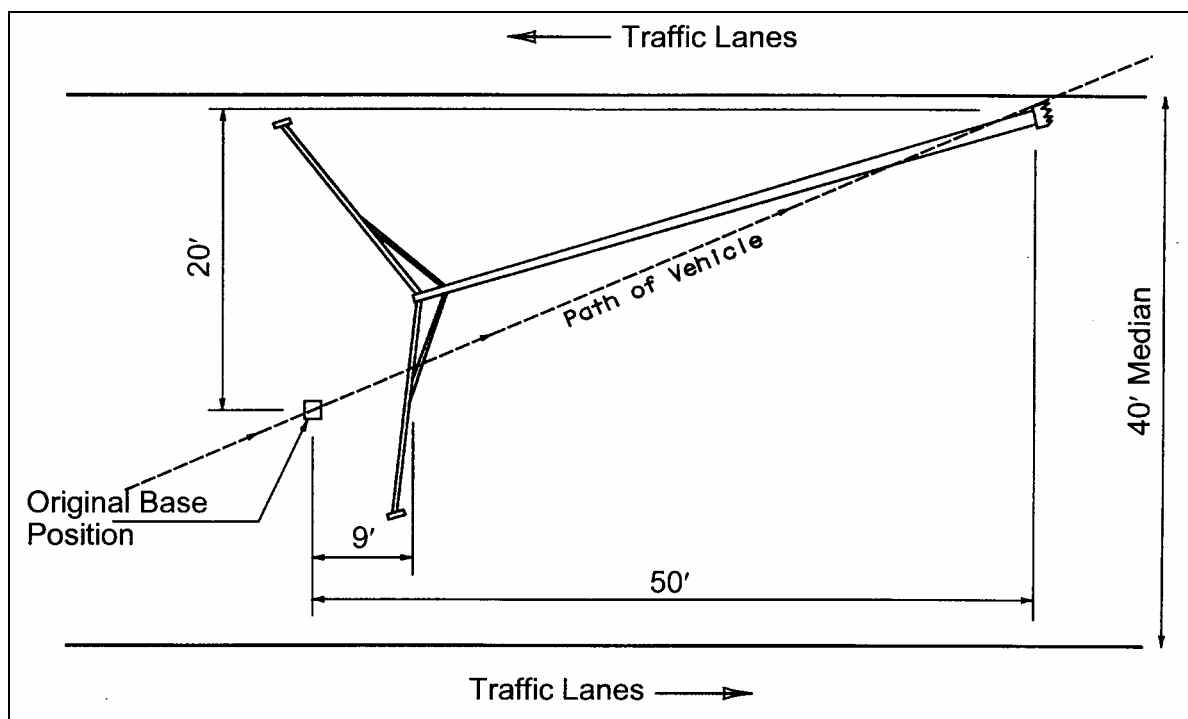


Figure 6-7. Falling area — final position of 50 feet luminaire support.

Example: In Figure 6-7, the falling area is calculated as follows:

$$\frac{2}{5} \times 50 \text{ ft. mounting height} = 20 \text{ ft. falling area}$$

Use and Placement of Breakaway Poles

Unprotected roadway lighting poles located inside the clear zone should be breakaway, unless conditions dictate otherwise.

Breakaway poles placed on the house side of interstate highways should be 15 feet from lane edge and should provide a clearance behind the pole of $\frac{2}{5}$ of the mounting height. For highways other than interstates, breakaway poles placed on the house side of travel lanes should be 15 feet from lane edge where practical. If sufficient right-of-way does not exist for this clearance, the poles may be placed just inside the right-of-way line but not closer than 2.5 feet from lane edge.

House Side Lighting

For house side lighting, the poles should be located as far from the shoulder edge as practicable. Generally, the minimum should be 15 feet from the lane edge.

Figure 6-8 shows typical house side lighting of a controlled access roadway with a median less than 30 feet wide. If the median width were 30 feet or greater, then median lighting could be used.

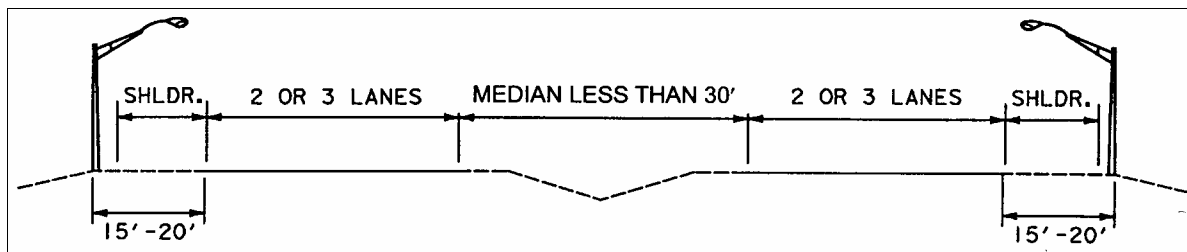


Figure 6-8. Typical house-side lighting for controlled access highway. In this example:

- Luminaires are 250 watt high pressure sodium (HPS).
- Mounting Height is 40 feet.
- Spacing varies (see Section 6 of this chapter, “Spacing of Light Poles”).

Median Lighting

Breakaway poles placed in medians should not be closer than $\frac{2}{5}$ of the mounting height from either main lane edge. Breakaway poles should not be placed in medians less than 30 feet wide, except as noted in the following paragraph.

(continued...)

Median Lighting (*continued*)

Median lighting in narrow medians should be avoided. If no other alternative is possible, an exception may be made for divided city streets with curbed medians, speed limit of 45 MPH or less, and where pedestrian traffic allows the use of breakaway poles. In this situation, breakaway poles may be used if placed at least 2.5 feet from any curb face, the pole height should not exceed 30 feet and pole mast arm lengths should not exceed 4 feet. Light poles should not be installed in urban median areas less than 30 feet wide if any other design is practical.

The turning lane of a divided city street may be included as part of the median width when determining the falling area. Remember, though, 2.5 feet offset from curb face should be maintained.

Breakaway poles placed in city street medians should also be placed at least one mounting height back from the end of the median at intersections.

Non-breakaway poles should not be placed in medians unless properly protected.

Median Lighting Design Examples

The following illustrations show typical median lighting designs for various controlled access roadway sections.

Example 1 — Unprotected Median: Figure 6-9 shows a typical median lighting design for a controlled access roadway having an unprotected median 30 feet or greater in width. Here breakaway poles should be used.

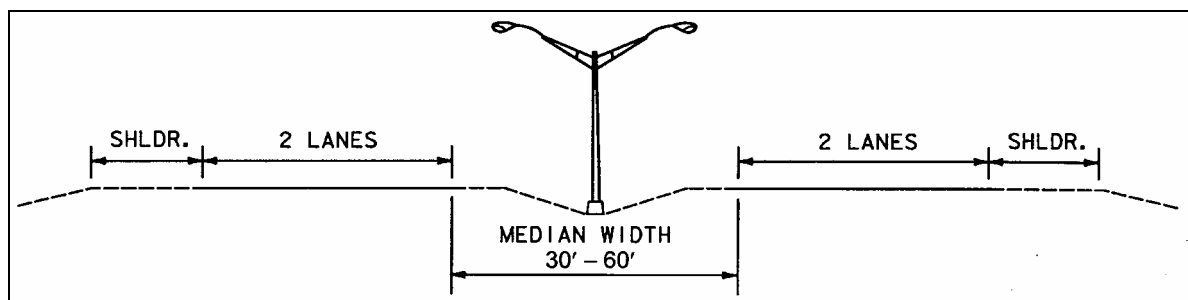


Figure 6-9. Median lighting with breakaway poles.

Note: Where median width exceeds 60 feet, it may be necessary to treat each main lane as a separate roadway, using two rows of poles in the median or house side (see Figure 6-8 for illustration of house side lighting).

(continued...)

Median Lighting Design Examples *(continued)*

Example 2 — Concrete Median Barrier: Figure 6-10 shows a typical median lighting design for a controlled access roadway having a concrete median barrier. Median width in this situation is typically 20 feet.

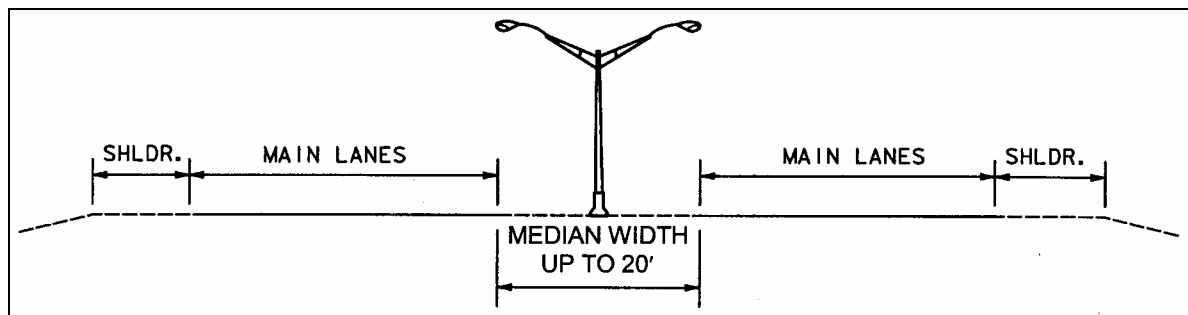


Figure 6-10. Median lighting with concrete median barrier.

The following table shows the recommended lighting for concrete median barriers.

Recommended Lighting for Concrete Median Barriers

Number of Lanes	Luminaires	Mounting Height	Spacing
2 or 3 each direction	250 watt HPS	40 feet	varies
4 or 5 each direction	400 watt HPS	50 feet	varies

Avoid Channelizing Islands

Avoid placing lighting poles in channelizing (dividing) islands, as the falling area of the pole is difficult to obtain except in cases where the island is very large.

Breakaway Pole Placement Examples

Figure 6-11 and Figure 6-12 show examples of breakaway pole placement and respective minimum applicable distances recommended for each of the cases listed in the following table.

Breakaway Pole Placement Cases

Case No.	Case	Shown in
1.	Median-mounted poles or poles inside the clear zone of two separate roadways.	Figure 6-11
2.	Outside clear zone of frontage road but inside the clear zone of main lanes.	Figure 6-11
3.	Outside clear zone of main lane but inside clear zone of frontage road.	Figure 6-11
4.	Minimum distance from ramp.	Figure 6-11
5.	House side of frontage road.	Figure 6-11
6.	Minimum distance from overhead electric lines (OHE).	Figure 6-11
7.	City street intersection.	Figure 6-12

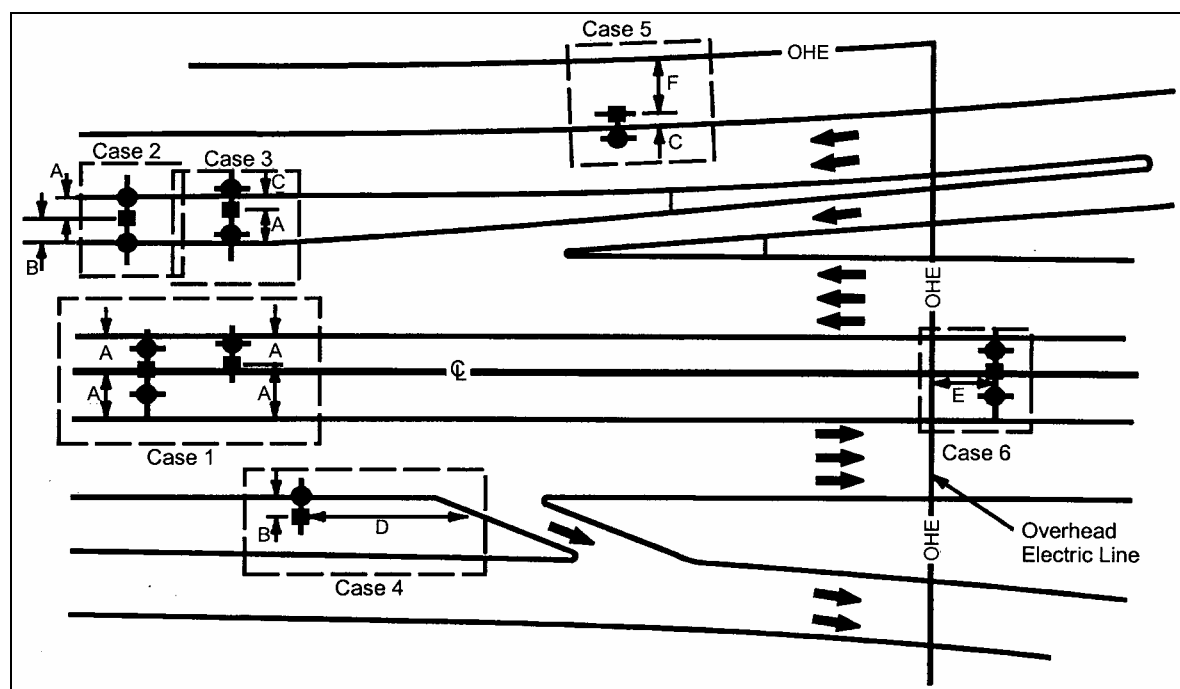


Figure 6-11. Controlled access facility illustrating example Cases 1 through 6. Minimum distances (designated here by the letters “A” through “G”) are shown in the following table.

(continued...)

Breakaway Pole Placement Examples (continued)**Minimum Distances**

(Indicated by Letter in Figure 6-11 and Figure 6-12)

- A. $\frac{2}{5}$ (40%) of one mounting height from edge of travel lane.
- B. 15 feet from edge of travel lane (20 feet desirable).
- C. Depends on whether or not the roadway is curbed or uncurbed and on the design speed (see following table).

Pole Offset from Roadway

Lane Edge	Design Speed	Distance from Curb Face or Lane Edge	
		Desirable	Minimum
Barrier Curb*	45 mph or lower	10 ft.	2.5 ft.**
Barrier Curb*	50 mph or higher	20 ft.	15 ft.**
Uncurbed	40 mph or lower	15 ft.	10 ft.**
Uncurbed	45 mph or higher	20 ft.	15 ft.**

* Curbed roadway denotes a roadway with a 6 inch minimum barrier-type curb. All mountable-type curb is considered as uncurbed.

** or as near ROW line as practicable.

- D. One mounting height.
- E. 20 feet, or as required by utility company.
- F. 8 feet, or as required by utility company.
- G. Clear zone.

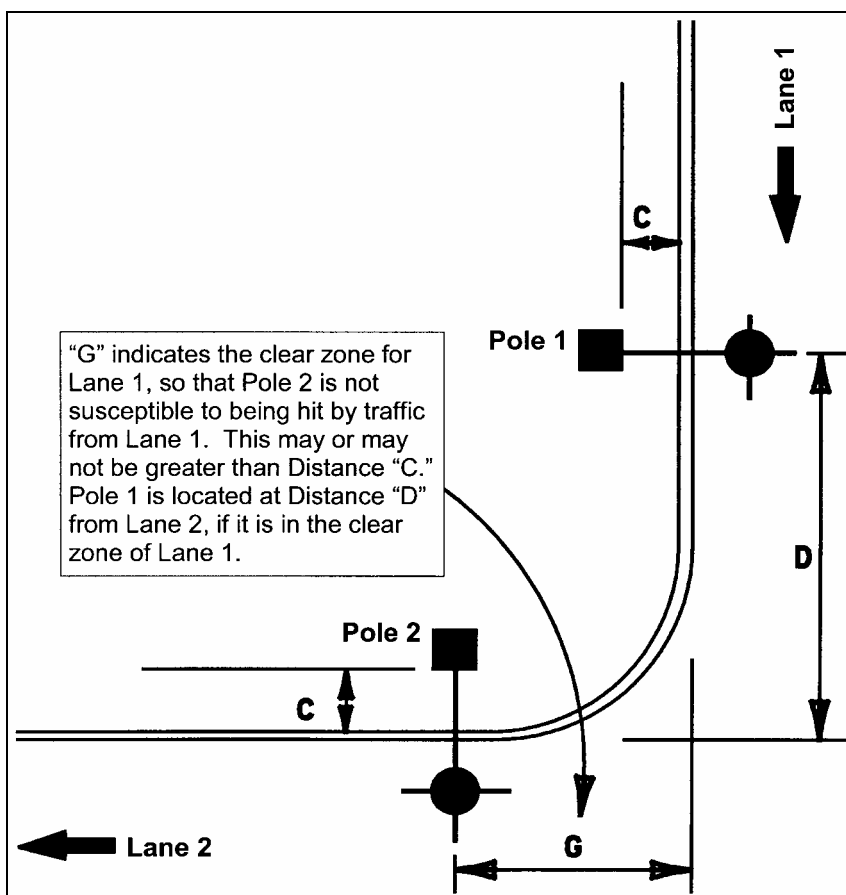


Figure 6-12. Example Case 7. Minimum distances (designated by letters) are shown in the preceding table.

Minimum Values

The distances shown and described in these guidelines as well as the clear zone definitions are minimum values. Even though breakaway poles may be placed in the clear zones, both breakaway and non-breakaway lighting poles should be placed as far away from the roadway as practical while maintaining the required light levels.

Poles in Sidewalks

The Americans with Disabilities Act (ADA) accessibility guidelines (36 CFR, Part 1191) stipulate that public sidewalks, where provided, must contain a continuous passage at least 36 inches wide. For this reason, the placement of poles in sidewalks should be avoided. Where such placement cannot be avoided, the sidewalk may need to be widened around the pole to maintain the required passage.

Foundation Height

Foundations for luminaire supports should be set flush with the ground line. Foundations placed on slopes should have the edge closest to the travel lanes flush with the ground.

Striking Height

Tests have shown that breakaway luminaire supports may not operate properly when the vehicle strikes the pole too high above the ground. Breakaway poles should, therefore, not be placed in areas where they are likely to be struck more than 28 inches above the top of the foundation. Limiting the negative side slopes to 1:6 between roadway and luminaire supports should ensure acceptable striking height.

Breakaway Pole Frangibility

Chapter 9, Section 3, provides a discussion of the frangibility requirements for breakaway poles.

Chapter 7

Electrical Systems

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Section 1

Overview

Introduction

Electrical system design involves many considerations. This chapter covers the areas of special concern to roadway illumination.

National Electrical Code

The National Electrical Code (NEC) contains nationally recognized rules and regulations for the installation and use of electrical power. The NEC is written by the National Fire Protection Association (NFPA) (see “References” in Chapter 1, Section 1, for information on obtaining the publication). Each section is written by committees of experts. The NEC is considered the minimum acceptable standard for a safe installation.

Most local authorities adopt the NEC into law. Although the NEC is not law on state property, it should be complied with to ensure safe installation of electrical systems. Allow exceptions only in special cases where the intent of the NEC is satisfied.

The following articles of the 2002 *NEC Handbook* are of particular relevance to roadway lighting, sign lighting, and traffic signals:

NEC Handbook Articles Relevant to Roadway Lighting

Number & Title	Number & Title
100 Definitions	342 Intermediate Metal Conduit: Type IMC
110 Requirements for Electrical Installations	344 Rigid Metal Conduit: Type RMC
200 Use and Identification of Grounded Conductors	348 Flexible Metal Conduit: Type FMC
210 Branch Circuits	350 Liquid-tight Flexible Metal Conduit: Type LFMC
215 Feeders	352 Rigid Nonmetal Conduit: Type RMC
220 Branch-Circuit, Feeder, and Service Calculations (Parts I & II)	356 Liquid-tight Flexible Nonmetallic Conduit: Type LFNC
225 Outside Branch Circuits and Feeders	358 Electrical Metallic Tubing: Type EMT
230 Services	362 Electrical Nonmetallic Tubing: Type ENT
240 Overcurrent Protection	396 Messenger Supported Wiring
250 Grounding	404 Switches
280 Surge Arresters	408 Switchboards and Panelboards
300 Wiring Methods	410 Luminaires (Lighting Fixtures), Lampholders, and Lamps
310 Conductors for General Wiring	450 Transformers and Transformer Vaults (Including Secondary Ties)
314 Outlet, Device, Pull and Junction Boxes; Conduit Bodies; Fittings; and Manholes	600 Electric Signs and Outline Lighting

Electrical Details

Current TxDOT electrical specifications are contained in the Electrical Details (ED) Standard Sheets of TxDOT's *Traffic Operations Standard Plans* (see "References" in Chapter 1, Section 1, for information on obtaining the publication).

Section 2

Electrical Service

Introduction

Before designing the electrical circuit, the designer must first determine the service type. This section explains the types of service available and other concerns related to electrical service.

Typical Service Types

The first consideration in electrical system design is determining the type of electrical service. The Electrical Detail standard sheets show four standard electrical service arrangements. These service types are shown in the following table.

Standard Electrical Service Types

Service Type	Description	Notes
Type A or C	480 volts, 3-wire with center ground	Three-wire branch circuits consisting of two line conductors and a ground.
Type T	120/240 volts, 3-wire with center ground (main lug only — no main breaker)	Used for traffic signals, traffic management systems, and irrigation systems. Not typically used for illumination (except at lighted intersections with traffic signals).
Type D	120/240, 3-wire with center ground (main breaker)	Used for traffic signals, traffic management systems, and irrigation systems. Not typically used for illumination (except at lighted intersections with traffic signals).

Service Types A and C are recommended for roadway lighting.

If 480 volts is not available, 120/240 volt, 3-wire service is recommended with luminaires served at 240 volts.

(continued...)

Typical Service Types *(continued)*

Figure 7-1 shows schematics of Types A and C service types and an alternate of Type A sometimes used.

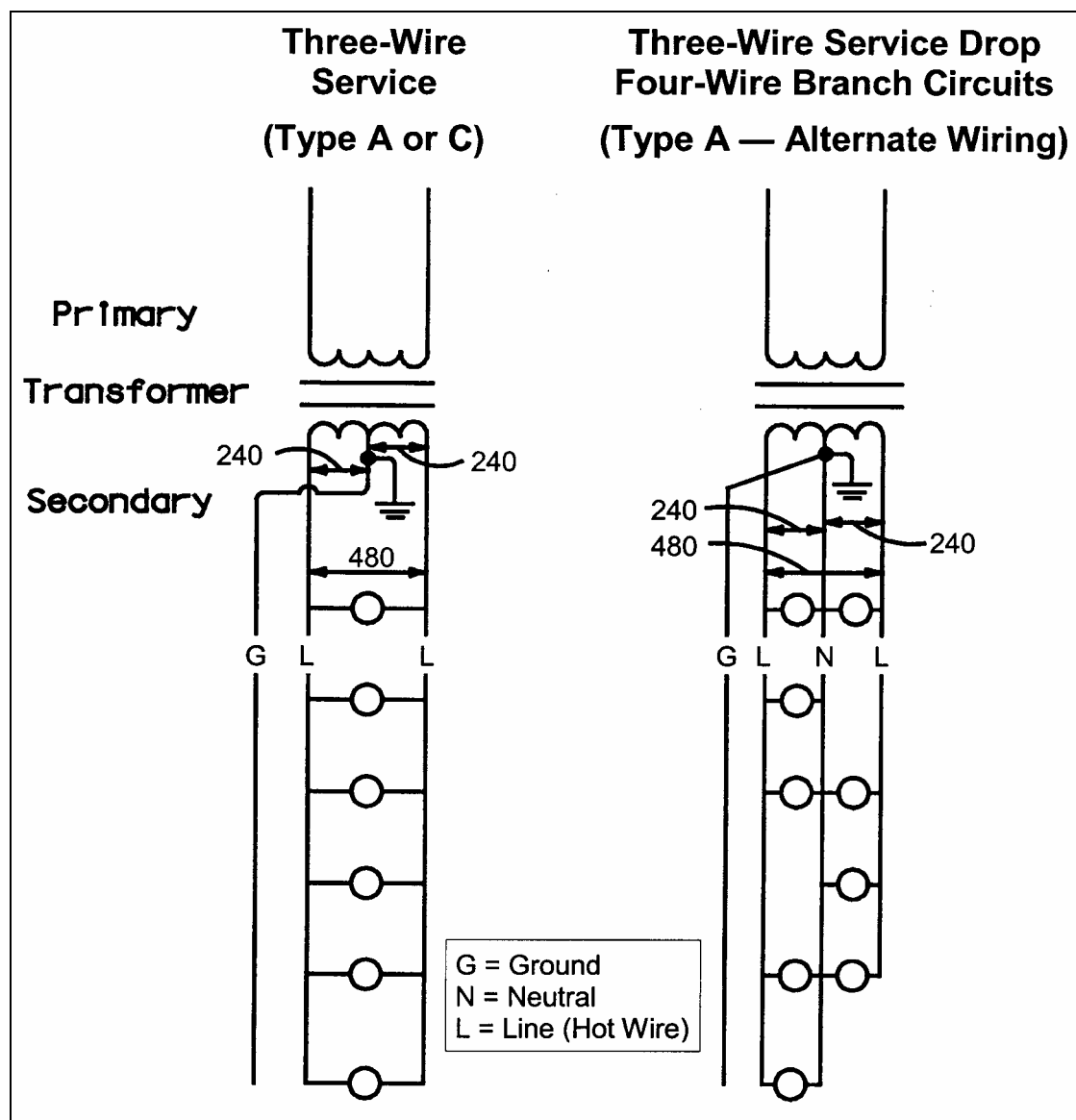


Figure 7-1. Typical electrical service types.

Note: Type A may also be used for 120/240 volt service. 480 volt to ground services must not be used.

Circuit Length Limits

At 480 volts, a 4,000 foot circuit of twin-arm poles can be served without unduly large conductors. At 240 volts, the circuit is limited to about 2,000 feet. (Conductor size and voltage drop are discussed in Section 3 and Section 4 of this chapter.)

Separate Electrical Service for Signs

Separately metered electrical service should be installed for sign lighting and roadway lighting. This is necessary because different entities usually maintain the two systems. TxDOT usually maintains the electrical service supplying sign lighting, while cities or others may maintain illumination. This separation of service also eliminates conflicts between maintenance organizations of the two entities. (For further information, see “Maintenance Responsibilities of Cities” in Chapter 9, Section 6.)

Where Service Does Not Exist

If there are no distribution lines near a necessary electrical service location, the utility company can provide cost estimates for extending service to these points. This cost should be charged to the project under a force account function code.

The contractor must consult with the appropriate utility company to determine cost and requirements, and must coordinate the utility work as approved by the engineer. The contractor will be reimbursed only the amount billed by the utility; no additional amount for supervision of the utility’s work will be paid.

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Section 3

Circuit Design

Introduction

Once the service type is determined, the circuits can be designed. This section covers the major considerations in the designing of roadway lighting circuits. Designers should refer to the *National Electrical Code (NEC) Handbook* for additional information.

Voltage Drop

The primary limitation on the length of circuits is the voltage drop. Section 4 of this chapter explains how to calculate voltage drop.

Conductors and Conduit Size

Another consideration is the number of conductors that can be installed in the various sizes of conduits. Annex C of the 2002 *NEC Handbook* shows the maximum number of conductors allowed in each conduit based on the capability of the wire to dissipate heat. However, with conduit runs of any substantial length, it is usually not practical to install the maximum number of conductors allowed in the conduit. A good rule of thumb is to limit the number of conductors to approximately one-half of the number shown in Annex C of the 2002 *NEC Handbook*.

The following tables provide dimensions for electrical metal tubing (EMT), Schedule 40 rigid metal conduit (RMC), and rigid non-metallic conduit (PVC).

Dimensions for EMT			
Size	I.D.	O.D.	Radius of Bends*
½	0.622	0.706	4
¾	0.824	0.922	4½
1	1.049	1.163	5¾
1¼	1.380	1.510	7¼
1½	1.610	1.740	8¼
2	2.067	2.197	9½
2½	2.731	2.875	10½
3	3.356	3.500	13
3½	3.834	4.000	15
4	4.334	4.500	16
* Radius to centerline of conduit for standard bends. Larger radius bends are available and are required for duct cable casings.			

(continued...)

Conductors and Conduit Size *(continued)***Dimensions for Schedule 40 RMC & Schedule 40 PVC**

Size	I.D.	O.D.	Thickness	Radius of Bends*
½	0.622	0.840	0.109	4
¾	0.824	1.050	0.113	4½
1	1.049	1.315	0.133	5¾
1¼	1.380	1.660	0.140	7¼
1½	1.610	1.900	0.145	8¼
2	2.067	2.375	0.154	9½
2½	2.469	2.875	0.203	10½
3	3.068	3.500	0.216	13
3½	3.548	4.000	0.226	15
4	4.026	4.500	0.237	16
5	5.047	5.563	0.258	24
6	6.065	6.625	0.280	30

* Radius to centerline of conduit for standard bends. Larger radius bends are available and are required for duct cable casings.

Conduit Run Length

As conduit run length and number of bends increases, the effort required to pull conductors also increases. Generally continuous conduit runs in excess of 700 feet are not recommended. Continuous conduit runs in excess 500 feet are not recommended when bends total 180 degrees. The NEC limits total conduit bends between pulling points to 360 degrees (no matter what the length of the run).

Overcurrent Protection

The ampacity of conductors is shown in Table 310-16 and accompanying notes of the *National Electrical Code Handbook*. This ampacity should be observed in sizing overload protection for the circuit.

When sizing overcurrent protection, the device closest to the load should be the smallest size. Devices should increase in size toward the service disconnect. For example, a 10 amp fuse might be used in the pole base where the branch circuit breaker is 20 amps, and the main disconnect is a 30 amp circuit breaker.

Electrical Service Equipment Sizes

Electrical service equipment sizes are based on the branch circuit load and the number of branch circuits. Note that all electrical equipment on the standard electrical service, except the lighting contactor, must be reduced to 80 percent of its rating (For example, only 40 design amperes is allowed on a 50 amp breaker.) The lighting contactors are rated for operation at full current rating.

The following tables show standard industry sizes of breakers.

Standard Circuit Breaker Sizes by Voltage

Voltage	Standard Circuit Breaker Sizes (Amps*)											
	15	20	30	40	50	60	70	100	125	150	175	225
120	X	X	X	X	X	X	X	X	X	-	-	-
240	X	X	X	X	X	X	X	X	X	-	-	-
480	-	X	X	X	X	X	X	X	X	-	-	-
600	-	X	X	X	X	X	X	X	X	X	X	X
* Remember, total load should not exceed 80 percent of circuit breaker rating.												

The standard lighting contactor sizes for all voltages are 30, 60, 100, and 200 amps.

Grounding Conductor Size

The Following table shows recommended equipment grounding conductor wire sizes for various size circuit breakers and branch circuit wire sizes. (The NEC allows smaller ground wire in a few cases.)

Grounding Conductor Wire Sizes

Branch Circuit Wire Size	— Branch Circuit Breaker Size* —							
	15	20	30	40	50	60	70	100
12	12	12	—	—	—	—	—	—
10	10	10	10	—	—	—	—	—
8	8	8	8	8	8	—	—	—
6	6	6	6	8	8	8	—	—
4	4	4	4	6	6	8	8	—
2	2	2	2	4	4	4	4	8
* Remember, total load should not exceed 80 percent of circuit breaker rating. Therefore, size the branch circuit breaker at 125 percent of the branch circuit current (or the next higher standard rating.)								

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Section 4

Calculating Voltage Drop

Introduction

This section explains voltage drop and how to calculate it for roadway illumination branch circuits.

Voltage drop can be calculated manually, using the methods described in this section or automatically using NEWVOLT, a program set up on Microsoft Excel.

Maximum Allowable Voltage Drop

Typical service line voltage for illumination is 480 VAC. However, since copper wire has some amount of resistance, a voltage drop (or loss) will occur in the wire itself. This energy is lost in the form of heating in the wire.

Magnetic regulator ballasts for HPS of the type specified for roadway lighting (and shown on Roadway Illumination Details) will operate properly at 10 percent under rated line voltage. (This is not true for all electrical equipment. For equipment other than roadway lighting, see the equipment manufacturer's documentation.) Good design practice allows the utility company 2 percent variation from rated line voltage, leaving 8 percent available for voltage drop in branch circuits. Therefore, the maximum allowable voltage drop for a 480 volt circuit would be 38.4 volts, derived as follows:

$$480 \text{ V} \times 0.08 = 38.4 \text{ V maximum allowable voltage drop.}$$

Formula

Voltage (V) is equal to current (I) times resistance (R), expressed as

$$V = I \times R$$

Therefore, voltage drop (Vd) in any given run may be calculated as

$$Vd = \frac{\text{Current in the run (amps)}}{\text{run (amps)}} \times \frac{\text{Conductor resistance (ohms per meter or ft.)}}{\text{(ohms per meter or ft.)}} \times \frac{\text{Length of the run (meters or feet)}}{\text{(meters or feet)}}$$

Discussions of each of the factors in this formula follow.

Current in the Run

When calculating voltage drop manually, the designer must determine the current in each run (that is, from the last light pole to the next-to-last, etc., all the way back to the service pole). The current depends on the number and type of fixtures. The following table shows the current required for the various types of fixtures.

Design Amperes for Various Luminaires

Lamp Wattage and Type*	— Line Voltage —		
	120 V	240 V	480 V
100 W MV	1.2 A	0.6 A	0.3 A
175 W MV	1.8 A	0.9 A	0.5 A
100 W HPS	1.2 A	0.6 A	0.3 A
150 W HPS	1.8 A	0.9 A	0.5 A
200 W HPS	2.4 A	1.2 A	0.6 A
250 W HPS	3.0 A	1.5 A	0.75 A
400 W HPS	4.2 A	2.2 A	1.2 A
40 W F	0.37 A	n/a	n/a
150 or 165 W IF	1.4 A	0.71 A	n/a

* MV = Mercury Vapor; HPS = High Pressure Sodium; F = Fluorescent; IF = Induction Fluorescent

Note: The amperage shown for MV and HPS fixtures is for magnetic regulator type ballasts only. If other types of ballasts are used, refer to the manufacturer's specifications.

Conductor Resistance

To calculate voltage drop, you need to know the resistance of the conductor (wire) used in the branch circuit. Resistance is a function of wire size and length. Resistance for both wires going to the luminaire must be considered.

The following table shows wire resistance for various American Wire Gages (AWG). Since both wires are the same size in typical circuits, the table shows “loop resistance”; thus the designer need only calculate the distance between luminaire poles.

Wire Resistance by Gage

Wire Size (AWG)	Loop Wire Resistance*	
	(ohms/foot)	(ohms/meter)
12	0.003360	0.011023
10	0.002036	0.006680
8	0.001308	0.004291
6	0.000820	0.002690
4	0.000518	0.001700
2	0.000324	0.001063
0	0.000204	0.000670
00	0.000162	0.000532

* Values shown are for uncoated copper conductors in conduit at 25°C.

(continued...)

Note: Loop resistance accounts for the wire run in both directions, requiring the designer to measure only the one-way distance between luminaire poles.

Larger wire sizes have lower resistances. Using larger wire is one way to reduce the voltage drop in the circuit.

Length of Run

When using the preceding table to obtain conductor resistance per meter or foot, the “length of the run” used in the voltage drop formula will simply be the one-way distance between the poles.

Because of the way luminaires are wired, the height of the pole is of no consequence in voltage drop calculations. Only at the last pole would the height be a factor, and then only if the pole were very tall (high mast, for instance).

Calculation Example

On a 480 volt branch circuit, the run from the last light pole to the next light pole is 200 feet. The twin-arm light pole supports two 400 watt HPS fixtures. The conductor is 8 gage wire.

Using data from the tables provided in this section, we obtain the following information:

- ◆ current in the run = 2×1.2 amps *or* 2.4 amps
- ◆ loop resistance of the conductor = $0.001308 \text{ } \Omega/\text{ft.}$

Using the formula for calculating voltage drop, we find

$$Vd = 2.4 \text{ amps} \times 0.001308 \text{ } \Omega/\text{ft.} \times 200 \text{ ft.}$$

and therefore

$$Vd = 0.628 \text{ volts.}$$

Total Voltage Drop

Each run of the branch circuit will have a voltage drop. Therefore, as you work toward the electrical service, the total voltage dropped in the wiring increases as the drop for each successive run is added. This total must not exceed 8 percent at the pole farthest from the electrical service. The 8 percent is based on a mag-reg ballast that operates at plus-or-minus 10 percent line voltage. The allowable voltage drop should be adjusted to accommodate the specific ballast used.

Split Branch Circuit

Sometimes a branch circuit splits and runs in two directions. When this happens, the designer must remember that each run split off the circuit has a separate voltage drop.

Chapter 8

Temporary Lighting

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Section 1

Design and Layout

Purpose

The purpose of temporary roadway lighting is to improve the ability of motorists to navigate the construction area.

Difference Between Temporary and Work Zone Lighting

Temporary roadway lighting is not the same as work zone lighting. Work zone lighting is installed so that the contractor may work at night. If work zone lighting is installed, care should be taken to ensure that the visibility of passing motorists is not reduced below an acceptable level. Temporary roadway lighting helps reduce the negative effect of work zone lighting.

Special Considerations

Some special considerations affecting the design of temporary lighting include:

- ◆ cost of system
- ◆ ease of installation
- ◆ ease of maintenance
- ◆ ease of moving the temporary poles.

Because the purpose of temporary lighting is to make it safer to travel through the construction area, the lighting should be installed in such a way as to limit glare and avoid the placing of hazardous obstacles near the travel ways.

Roadway delineation should be considered along with any temporary lighting requirements.

Types of Temporary Lighting

Some possible types of temporary lighting systems include:

- ◆ standard steel poles with or without breakaway bases
- ◆ wood poles, 30- or 40-foot mounting height, protected from traffic, with standard highway light fixtures
- ◆ short poles mounted on concrete traffic barriers with low wattage delineator type lighting — examples include:
 - 70 watt HPS wallpack type fixtures on 4 × 4 inch × 8 foot poles on top of or behind barriers
 - rail mounted fluorescent fixtures
 - floodlighting from just inside or outside of the frontage road
- ◆ permanent high mast illumination installed early in project.

Illumination Levels

Illumination levels should be higher than normal, where practicable, in detour areas, gore areas, and other construction zone obstacles (impact attenuators, etc.).

Illumination levels and uniformity may be lower than normally required in areas where the motorist has no special navigational decisions to make.

Lighting systems should not create excessive glare, a potential problem with low mounting heights.

Electrical System Integrity

Electrical safety and integrity must be maintained in temporary lighting. Follow these guidelines:

- ◆ Where breakaway poles are used, breakaway electrical devices should also be used.
- ◆ Overhead wiring may be considered where non-breakaway poles are used.
- ◆ Voltage should not exceed 277 VAC to ground for temporary lighting units mounted at 18 feet or less.
- ◆ Portable cord or other temporary wiring may be used in lieu of buried conduit and conductor systems.
- ◆ It is sometimes cost effective to use permanent lighting service pole locations for the temporary system.
- ◆ Usually fused fixtures and non-fused breakaway disconnects are preferable for temporary lighting.

Placement of Light Poles

All poles located within the clear zone should be of the breakaway design or should be otherwise protected from vehicle impact (behind concrete barriers or guard rail). (See Chapter 6, Section 7, for more details.)

Installation

If practicable, temporary lighting should be installed before the existing lighting is disabled.

Plans and Specifications

Temporary lighting plans should show:

- ◆ the type and number of units required
- ◆ locations, spacings, and offsets of poles
- ◆ bracket and pole details
- ◆ electrical connection details, such as:
 - electrical services
 - conduit and wire or cord runs
 - strain pole connections and guys (if used)
 - breakaway disconnects (if used).

Temporary lighting should be coordinated with traffic control plans, which should show where and when the poles are to be placed or relocated.

Specifications for fixtures, wiring, poles, and services should be included with the plans when non-standard items are used. Ensure that circuit voltage drop is compatible with the ballasts of fixtures selected. Magnetic regulating ballasts are recommended, because they tolerate ± 10 percent line voltage variation.

Section 2

Financing

General

Roadway construction contracts should make maintenance of the roadway lighting system — including temporary lighting — the contractor's responsibility. The state, however, should pay for the electrical energy charges.

Method of Payment

There are two methods for measuring and paying for temporary illumination.

Lump Sum. Lump sum is the most frequently used method of paying for temporary lighting. This method is also the most expensive for the state, as the contractor is forced to include in his bid unexpected costs for contingencies such as knocked down poles. For the lump sum method, the plans and specifications must be precise, because variations require field changes.

By the Unit. A more desirable method of paying for temporary lighting is by each unit or part of a unit. This method is much more flexible and should provide significant cost savings for the state. Recommended descriptive codes (all under the special specification "Temporary Lighting") include:

- ◆ light fixture, including connectors and fuses, by each
- ◆ pole or bracket, by each
- ◆ wiring and conduit, by the foot
- ◆ temporary service pole, by each
- ◆ relocate temporary light pole, by each pole relocated.

Reusable Equipment

If equipment installed for a temporary lighting system can be reused, the contractor should be required to turn over to TxDOT such equipment quantities as paid for in the contract and not damaged by motorists, in good condition, delivered to a site as directed by the engineer.

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Chapter 9

Construction and Maintenance Guidelines

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Section 1

Overview

Introduction

This chapter addresses issues of concern to construction and maintenance personnel. Design personnel can also benefit from the information provided here.

Section 2, “Review and Approval of Shop Drawings,” primarily concerns construction personnel.

Section 3, “Breakaway Light Poles,” is of concern to both construction and maintenance personnel.

The remaining sections address maintenance issues.

Consistency

Consistency in the areas of illumination, electrical plans, project electrical inspection, and electrical maintenance is important. Districts can better achieve consistency if one person has specific control of all illumination and electrical plans and one or more inspectors specialize in illumination and electrical projects.

Chapter 1, Section 1, of this manual recommends specific training and experience for TxDOT personnel involved with highway illumination.

Assistance

The Traffic Operations Division (TRF) is available to help with design, construction, maintenance, and training upon request. Districts should feel free to take advantage of their illumination and electrical systems expertise.

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Section 2

Review and Approval of Shop Drawings

District Review and Approval

Shop drawings for conventional light poles may be reviewed and approved at the district level for both:

- ◆ contract projects (except high mast) *and*
- ◆ district-originated purchase requisitions.

TRF assists with the review of any illumination or electrical submittals when requested by a district.

TRF coordinates with the Bridge Division (BRG) to review shop drawings for roadway illumination poles.

For Purchase Requisition

Suppliers must submit shop drawings for lighting poles on purchase requisition for general warehouse stock to the General Services Division (GSD) for the review and approval of TRF.

Breakaway Poles

For breakaway poles, manufacturers are required to submit shop drawings with the structural strength test results and the breakaway certification. Districts wishing to have breakaway pole and transformer base designs reviewed, may send the shop drawings to TRF.

High Mast Lighting

BRG reviews and approves high mast pole shop drawings. TRF reviews and approves drawings of high mast assemblies. Contractors should submit shop drawings for these items accordingly, *unless otherwise shown on the plans*. Districts desiring to review drawings themselves, may include a general note in the plans to that effect. However, due to the complicated and critical nature of high mast assemblies, it is recommended that TRF review these shop drawings.

Contractors should direct the brochure submittal required by Standard Specification Item 614 and other submittals pertaining to electrical matters to TRF for review and approval.

Copies to Materials and Tests Section

The Construction Division's (CST) Materials and Tests Section performs shop inspections. Therefore, the division or office approving shop drawings for lighting poles and assemblies must forward two copies of all approved shop drawings to the CST Materials and Tests Section.

Marking of Shop Drawings

Shop drawings should be marked as "approved" or "approved except as noted" or "returned for correction." Approval marking should be on the drawing itself instead of only by an accompanying letter.

Section 3

Breakaway Light Poles

Frangibility Requirement

The FHWA adopted Section 7 of the 1985 AASHTO publication entitled “Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals” for implementation beginning in July 1990. This section requires more stringent breakaway characteristics. TxDOT’s previous design of roadway illumination assemblies (based on a 1975 AASHTO specification) does not meet these requirements.

Breakaway light poles rely on frangible transformer bases to provide the breakaway feature. The 1985 AASHTO specification provides for a maximum change in momentum of a 1800 pound car to break the pole away. The 1975 AASHTO specification provided for a similar change in momentum except that the test vehicle weighed 2,250 pounds.

Structural Requirement

While providing the necessary frangibility, the base must also be structurally adequate to support the illumination pole for design wind speeds. Transformer bases meeting the ’85 AASHTO specification may not adequately support some 50 foot steel poles, notably those designed to meet the ’75 AASHTO specification.

Replacement Guidelines

Lighting systems built under the previous requirements should be maintained with ’75 AASHTO standard poles and transformer bases currently in stock.

Replacement transformer bases for lighting systems built under the ’85 AASHTO requirements should be specified to be the same model number as the bases being replaced. This model number is required to be incised on the base.

Two variables of pole construction affect structural compatibility with the ’85 AASHTO transformer bases top: bolt circle and base plate thickness. No tolerances for these variables have been established. For this reason, TxDOT does not recommend the direct replacement of ’75 AASHTO standard transformer bases with ’85 AASHTO standard transformer bases for 50 foot steel poles.

New Installation Guidelines

Current breakaway requirements can be met on new installations by using the new transformer base and pole designed for that base, both approved by the FHWA to meet '85 AASHTO standards.

TxDOT typically uses breakaway poles wherever possible, even when not required. For these types of new installations, where breakaway poles are used but not required (outside the clear zone or behind barriers), transformer base poles meeting the '75 AASHTO guidelines may be used when currently in stock but should not be considered breakaway.

Do not use shims or washers to level the '85 AASHTO breakaway base, because this may change the breakaway characteristics of the base. Ensure that the top of the concrete foundation is level.

Relocated Poles

Relocated light poles should be upgraded to the '85 AASHTO breakaway requirements and should be of a design that has been tested with the '85 AASHTO base.

Poles Placed by Maintenance Forces

New light poles placed by maintenance forces should meet all safety related guidelines set forth in Chapter 6, Section 7, of this manual and the '85 AASHTO breakaway requirements. This includes breakaway poles installed by maintenance forces at new locations.

Guidelines Apply to Cities

Cities installing light poles or maintaining lighting systems on state right-of-way must abide by these same guidelines.

Districts should keep city maintenance personnel informed of the different system requirements and the allowable uses of the various transformer bases.

Review of Shop Drawings

See Section 2 of this chapter for discussion of review of shop drawings for breakaway light poles.

Identifying Transformer Bases

The old and new transformer bases can be distinguished from each other by height and model number. The old bases are 20 inches tall, while the new ones are 17 inches tall. All new base model numbers have “-17” as the last three digits.

Striking Height

Tests have shown that breakaway luminaire supports do not operate properly when the vehicle strikes the pole too high above the ground. Breakaway poles should, therefore, not be placed in areas where they are likely to be struck more than 28 inches above the top of the foundation. Limiting the negative side slopes to 1:6 between roadway and luminaire supports should ensure acceptable striking height.

Anchor Bolts

Torque anchor bolts to manufacturer’s recommendation. This will help to ensure proper operation of the pole and breakaway device.

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Section 4

Group Relamping

Background

Group relamping involves the replacement of all lamps in an illumination system on a regular schedule. This period is known as the group relamping interval. Group relamping should be considered in the maintenance of any illumination system so as to better utilize TxDOT resources.

Advantages

Group relamping improves the illuminance level while possibly reducing the costs involved in operating the system. Several important elements determine the cost of maintaining an illumination system, including the cost of labor, equipment, and traffic control. Increased costs require TxDOT employees to seek innovative and less expensive ways to perform maintenance functions. Group relamping is an attractive alternative to spot replacement of lamps, because the costs for labor, traffic control, and equipment use are greatly reduced. Group relamping also lends itself well to contracting.

Strategy

Group relamping should be scheduled every three to five years. Group relamping should be planned in advance of the need for lamp replacement. Adequate traffic control, in accordance with the *Texas Manual on Uniform Traffic Control Devices* (TMUTCD), should be provided to assist motorists around the work zone and to provide added safety for maintenance crews. Other maintenance functions such as ballast replacement, igniter (starter) replacement, or fixture replacement and cleaning should be accomplished during group relamping.

Cleaning Luminaires

Cleaning of the luminaires, which involves wiping the dirt from reflectors and refractors, should be performed during group relamping. This periodic cleaning of the fixtures reduces the depreciation of light due to the accumulation of dirt and allows the delivery of more light per lighting dollar. Allowing the illumination system to provide more consistent illuminance throughout the life of the lamps provides the motorist with better visibility and TxDOT with a more cost efficient lighting system.

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Section 5

High Mast Lighting Inspection and Servicing

Introduction

Inspect high mast lighting poles and assemblies and provide proper preventive maintenance. The inspection and servicing routine outlined in this section should be performed *every time the lamps are changed or the ring is lowered for any reason*.

For general guidelines on maintenance practices related to highway illumination, see the *Maintenance Operations Manual*, Chapter 4, Section 3. Also the *Maintenance Management Manual*, Chapter 3, explains the “maintenance level of service” concept, and Section 2 of that chapter provides the maintenance level of service guidelines for highway illumination.

Documentation (Inspection Form)

Personnel carrying out inspections of high mast lighting should document their findings using the Inspection Record for High Mast Lighting Pole Assembly form (TxDOT 1409) or a similar form. Districts must retain these completed inspection forms for a minimum of three years.

A sample inspection form is provided in Appendix A. This sample may be photocopied as necessary. Copies may also be obtained from TRF. A Microsoft Word version of this form is also available through the online version of this manual (click on the form number above).

Items to Inspect

The entire lighting assembly and pole should be inspected each time the ring is lowered for maintenance. Items to be checked and maintained during these inspections are listed on Form 1409 in the form of a check list.

Replacing Fixtures

Replacement fixtures for high mast lighting must be obtained by special order. There are many different types of fixtures on the various high mast poles. Each fixture is selected based on critical photometrics. Each fixture must be replaced *only* with an exact equivalent.

Fixtures must be aimed in exactly the correct direction.

The fixture catalog number can be obtained from the fixture or from submittals made on the construction project. These submittals also show how to aim the fixture.

Responsibility of Cities

High mast lighting assemblies, which by agreement are the maintenance responsibility of a city, should also be inspected and serviced as set forth in this section. This work may be performed by the city or its agent. When this inspection and servicing is performed by the city or its agent, districts should occasionally check that the work is performed correctly.

Districts should provide a copy of the shop drawings (pole and high mast ring), submittals, and “as built” plans to cities that are maintaining high mast lighting.

Assistance

Further assistance with high mast lighting inspection and servicing may be obtained from TRF.

Construction and maintenance videos are available through TRF.

Section 6

Other Maintenance Considerations

Duct Cable

Duct cable is a conduit system and must be treated as such. If the system is damaged the duct may be spliced, however, the electrical conductors in the duct cannot be spliced inside the duct. Depending on the length of the duct run, maintenance personnel may want to remove the existing wire and pull new conductors or consider placing a ground box and splicing the conductors.

If the conductors are spliced, a UL approved compression-type or split-bolt connector must be used to make the splice. Heat shrink tubing or gel caps are the only recommended splice insulators. Where two or more conductors enter one heat shrink tube, wrap the conductors with heat shrink tape. Heat shrink tubing must then be applied to insulate the splice. It is important to note that when duct cable is severed to make a splice, the ends of the duct must be cut straight and neat. Ends must also be reamed to remove sharp edges.

Grout

Prior to about 1975, grout was required to be placed between the illumination pole base plates and concrete foundations. Since then, it has been determined that such grout placement under pole or sign bridge base plates causes moisture to become trapped. This, in turn, contributes to excessive corrosion of the pole, support, base plate, anchor bolts, nuts, and other appurtenances.

It is imperative, therefore, that this grout be removed from under existing poles and not placed under newly installed poles. Anchor bolts should then be cleaned and painted with zinc rich paint. If severe deterioration is discovered, a more detailed investigation should be made into the remaining strength of the bolts.

Rehabilitation of Old Circuits

For older roadway illumination systems where maintenance requirements are excessive due to faulty circuits, rehabilitation of the circuits by TxDOT should be considered to reduce city maintenance costs.

When practicable, existing two-wire circuits should be replaced with a three-wire system that includes a continuous grounding conductor.

Maintenance Level of Service

The *Maintenance Management Manual* establishes guidelines for planning and performing various maintenance activities in accordance with available funds. Three possible funding levels are defined: desirable (the highest), acceptable, and tolerable (the lowest).

Maintenance priorities are assigned based on the level of funding, and maintenance forces are directed to “substantially maintain” the various highway components accordingly.

Chapter 3 of the *Maintenance Management Manual* explains the concept in detail, and Section 2 includes the maintenance level of service guidelines for highway illumination.

For general guidelines on maintenance practices related to highway illumination, see the *Maintenance Operations Manual*, Chapter 4, Section 3.

Maintenance Responsibilities of Cities

Maintenance of freeway illumination systems provided by some cities under agreement with the TxDOT sometimes falls below acceptable levels. Unless an adequate level of lighting maintenance is being provided by a city, no further agreements for city maintained illumination should be executed with that city until corrective action is taken.

Problems

Maintenance problems involving electrical and illumination design and materials should be brought to the attention of TRF so that possible alterations can be made on the *Traffic Operations Standard Plans*.

Appendix A

Forms

Contents

The print version of this appendix contains a copy of the following form.

Highway Illumination Forms

TxDOT Form Number Form Name	
1409	Inspection Record for High Mast Lighting Pole Assembly

This form may be photocopied as necessary. Copies may also be obtained from the Traffic Operations Division (TRF).

Automated versions of this form is available through the online version of this manual (click on the form number).

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Glossary of Terms and Formulae

Introduction

The following terms and formulae appear in this manual and in discussions of highway lighting. For electrical terms not listed here, consult the National Electrical Code (NEC).

AASHTO - American Association of State Highway Transportation Officials.

alternating current (AC) - Current and voltage alternates from maximum positive to maximum negative in a sinusoidal pattern.

ampere (I) - The unit of current strength (flow of electrons).

ballast - A device that includes a transformer that modifies incoming voltage and current to provide the circuit conditions necessary to operate electric discharge lamps.

blanket agreement - Agreement identifying lighting projects authorized under the agreement by making the plans an attachment to the agreement. The agreement must have a statement that appears on the title sheet of the plans identifying the plans as part of the agreement. This statement must be signed by the appropriate city official.

breakaway support - A lighting pole support designed to shear easily under vehicular impact. The breakaway feature can be an aluminum transformer base, a frangible insert between pole base foundation, a slip base, or other device. The breakaway support must meet current AASHTO and FHWA requirements.

candela or candlepower (cd) - The unit of luminous intensity (I) emitted by a light source in a given direction.

capacitance (C) - Ability to store energy in an electrostatic field. Measured in farads or microfarads.

clear zone - (also called the *clear recovery area*) The area provided along highways to allow vehicles veering off the travel lane opportunity for safe recovery or stopping. The clear zone width (always measured from the edge of the travel lane) depends on several roadway factors. The *Roadway Design Manual* contains a full discussion of the clear zone ("Horizontal Clearance to Obstructions") and provides the minimum and desirable widths for various roadways.

complete interchange lighting - The lighting, within the limits of the interchange, of the main lanes, direct connections, ramp terminals, and frontage road-crossroad intersections. (See partial interchange lighting.)

concrete median/traffic barrier (CTB) - Concrete traffic barrier.

conductor - Electrical wire, bare or insulated.

continuous lighting - Roadway lighting providing uniform illumination on all main lanes and direct connections and complete lighting for all interchanges.

conventional lighting - A highway lighting system in which the luminaires are typically mounted no higher than 50 feet. (See also high mast lighting.)

cosine law - The mathematical expression of the principle that illumination of a surface is proportional to the cosine of the angle (A) of incidence of the light beam.

cutoff - A luminaire light distribution is designated as cutoff when the candlepower per 1,000 lamp lumens does not numerically exceed 25 (2.5 percent) at an angle of 90 degrees above nadir (horizontal), and 100 (10 percent) at a vertical angle of 80 degrees above nadir. Cutoff type luminaires usually have flat glass lenses.

direct current (DC) - One-direction flow of electricity.

electrical details (ED) - TxDOT's standard sheets showing specifications for electrical specifications. Contained in the *Traffic Operations Standard Plans*.

EMT - Electrical metal tubing.

electrical service - Point of receiving power from utility company. Typical service voltages used on highway electrical systems are 120/240 VAC, 240/480 VAC, and 480 VAC.

FHWA - Federal Highway Administration.

floodlight - An aimable luminaire generally employed for spot or wide-angle lighting.

footcandle (FC) - English unit of measurement for the illumination (E) on a surface. (See "lux" for metric.) One footcandle is the illumination on a surface that is one foot from and perpendicular to a uniform point source of one candela. Combining the inverse square law and the cosine law, the formula for footcandles (FC) is

$$FC = \frac{CD \times \cos A}{D^2}$$

where *CD* is the candlepower, *A* is the angle of incidence of the light beam (see diagram under "lux,") and *D* is the distance of the surface from the light source.

frangible - Readily or easily broken.

High Mast Illumination Details (HMID) - The TxDOT's standard sheets showing specifications for high mast illumination. Contained in the *Traffic Operations Standard Plans*.

high mast lighting - Lighting units mounted at heights of 100 feet or more.

igniter – (See "starter.")

Illuminating Engineering Society of North America (IESNA also IES) - The IESNA writes many of the industry standard specifications for lighting fixtures.

inductance (L) - Ability to store energy in electromagnetic field. Measured in henrys or millihenrys.

inverse square law - Expresses mathematically the relationship between luminous intensity (CD) and illumination (FC). It states that illumination at a point on a surface is directly proportional to the luminous intensity of the light in that direction and inversely proportional to the square of its distance (D) from the source.

$$FC = \frac{CD}{D^2}$$

iso-lux (or iso-footcandle) curves - Curves plotted from metered photometric readings for a specific lighting unit, of a particular design and rated wattage, when the unit is mounted at a certain height. These readings are taken on a rectangular grid that is oriented from the center of the light source. From such readings, contour lines are then plotted for identical values in lux (footcandles); and when contours are plotted for equal increments of increase in illumination intensity, the resulting contour lines produce a series of generally concentric semiparabolic curves, described as iso-lux (iso-footcandle) curves.

kilovolt-amp (KVA) - A measure of apparent power. Equipment is rated in KVA when heat dissipation is a concern (transformers are rated in KVA).

$$KVA = Volts \times \frac{Amps}{1000}$$

kilowatt (KW) - A measure of real power (generators, lamps, and heating elements are rated in watts or kilowatts).

$$KW = Volts \times Amps \times \frac{power\ factor}{1000}$$

(1KW = 1.34 horse power)

lamp - (See "light source.")

light source - The device that converts electric energy to visible light (also called the "lamp").

lumen (lm) - The unit of quantity of light flux; in other words, the total output of a light source.

luminaire - A device that directs, controls, and modifies the light produced by a light source. It consists of a light source, reflector, refractor, housing, and such support as may be integral with the housing.

lux (lx) - Metric unit of measurement for the illumination (E) on a surface. (See footcandle for English unit.) One lux is the illumination on a surface one meter from and perpendicular to a uniform point source of one candela.

Combining the inverse square law and the cosine law, the formula for lux is

$$lx = \frac{CD \times \cos A}{D^2}$$

where *CD* is the candlepower, *A* is the angle of incidence of the light beam (see Figure G-1), and *D* is the distance of the surface from the light source.

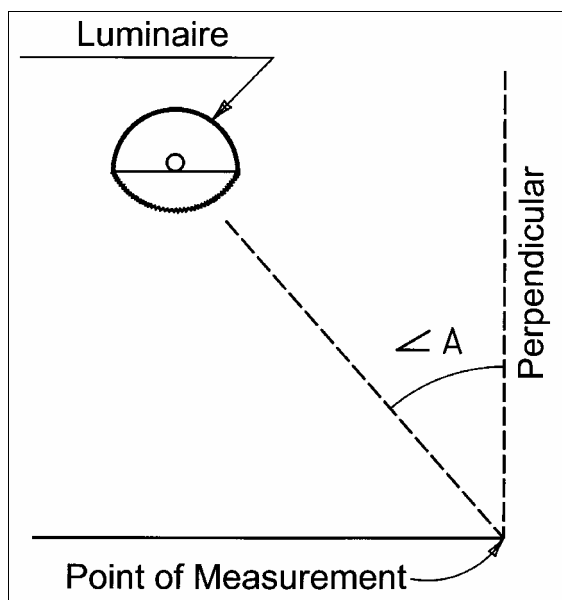


Figure G-1. Measuring the angle of incidence of a light beam.

mast arm - An attachment to a lighting pole on the end of which a luminaire is mounted.

mounting height - Generally the vertical distance between the base of the pole and the luminaire.

National Electrical Code (NEC) - Nationally recognized rules and regulations for the installation and use of electrical power. The NEC is considered the minimum acceptable standard for a safe installation.

National Electrical Manufacturer's Association (NEMA) - Provides specifications and industry standards.

ohm (R) - The unit of electrical resistance.

partial interchange lighting - The lighting of acceleration and deceleration lanes, ramp terminals, crossroads at frontage road or ramp intersections, and other areas of nighttime hazard. (See "complete interchange lighting.")

photometric curves - (Also called "photometric data.") Derived from metered measurements of horizontal or vertical lux (or footcandles). These metered measurements are obtained by the use of a light meter usually calibrated in lux (or footcandles).

pole - A galvanized steel or aluminum shaft to support the lighting unit (also called "lighting standard").

power (P) - Measured in watts. Formulae as follows:

- ◆ for DC circuits: $P = EI$ or $P = VI$
- ◆ for AC circuits: $P = EI(pf)$ or $P = VI(pf)$.

For power loss due to resistance in lighting circuits, the power factor can be considered equal to one. This power can also be calculated: $P = I^2 R$.

power factor (pf) - Time relationship between current wave and voltage wave in an A.C. system.

PVC - Polyvinyl chloride, the material of which a kind of tubing used for conduit is made.

reflector - Polished aluminum device used to reflect light.

refractor - Prismatic glass element used to refract light.

regulated output ballast - A form of electrical transformer that maintains the wattage of the lamp at a nearly constant value, though the line voltage may fluctuate as much as ± 10 percent. Such Ballasts or transformers may be integrally mounted within the luminaire or separately mounted in a ballast enclosure.

RMC - Rigid metal conduit.

roadway illumination assembly - The luminaire and supporting members (pole, mast arm, etc.) with other related lighting equipment attached.

Roadway Illumination Details (RID) - The TxDOT's standard sheets showing specifications for roadway illumination to be used with TxDOT standard specification Items 610, 611, 612, and 656. The details are contained in the *Traffic Operations Standard Plans*.

safety lighting - Roadway lighting installed at interchanges, highway intersections, and other points of nighttime hazard to the extent necessary to provide for the safe and orderly movement of traffic.

spacing - The distance between successive lighting units measured along the center line of the roadway.

starter or starting aid (also called igniter) - A device producing a high voltage pulse to begin arcing in a lamp.

transformer - An electrical device that changes one AC voltage to another. Utility companies generate and distribute power at voltages usually greater than 12,500 VAC. Transformers reduce the voltage to a safe and easily applied level, 120 VAC for typical receptacles.

transformer base - A hollow cast aluminum base, the bottom of which is bolted to a concrete foundation and to the top of which the bottom flange of the pole is bolted.

uniformity - The ratio of the average level of illumination to the minimum level of illumination on the roadway.

volt (V or E) - The unit of electromotive force, electrical pressure, or difference of potential. Analogous to water pressure. One volt will cause one ampere of current to flow through a resistance of one ohm.

voltage drop - A result of current flowing through a resistance.

$$V = I \times R$$

Example: A current of 30 amperes flowing through 300 feet of No.8 conductor whose resistance loop is 0.3924 ohms will result in a voltage drop of 11.77 volts.

warrant - Warrants are applied to determine whether or not the lighting system is justifiable at a particular location on an eligible highway.